Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 16
MAY
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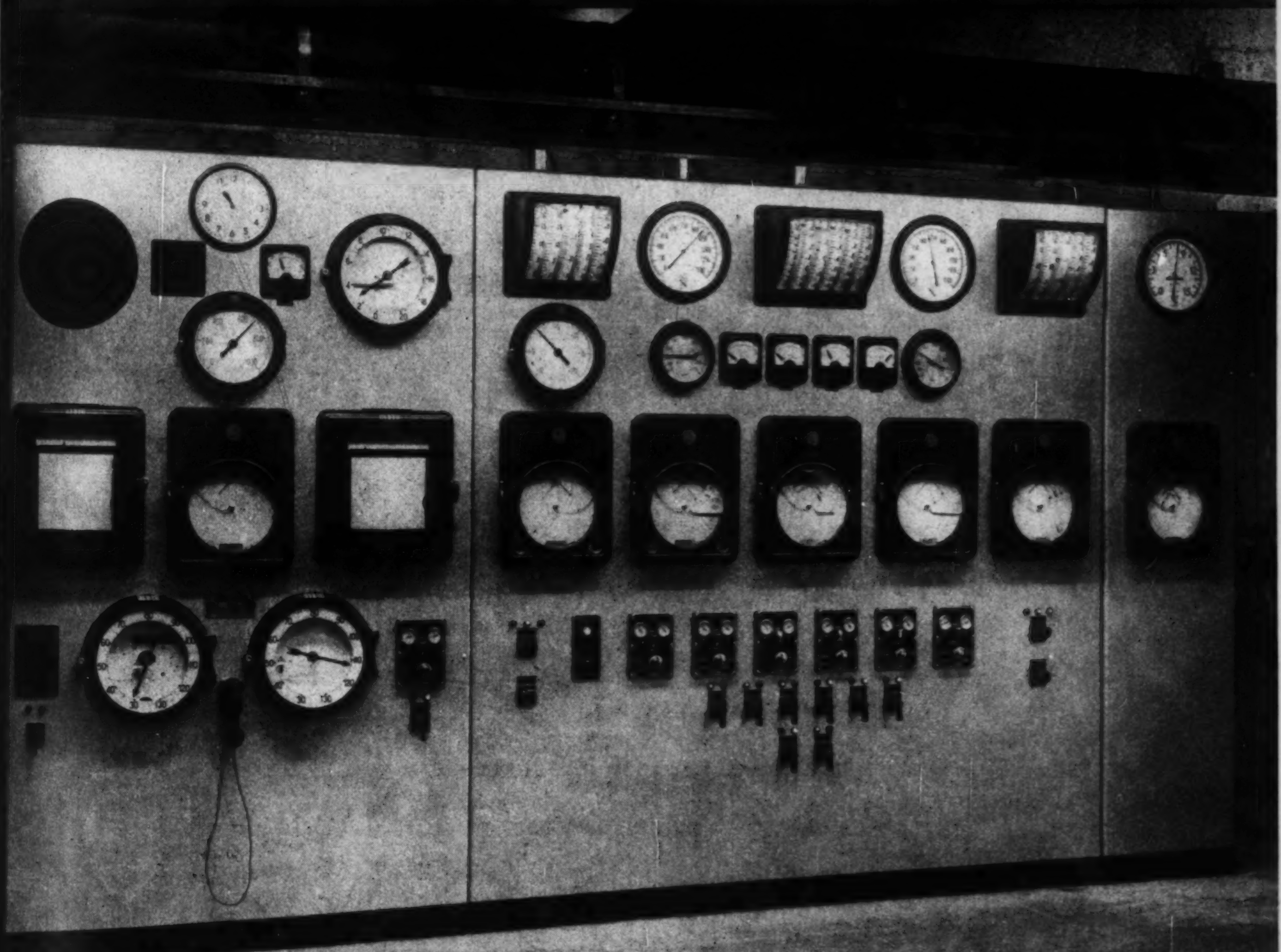
No. 5



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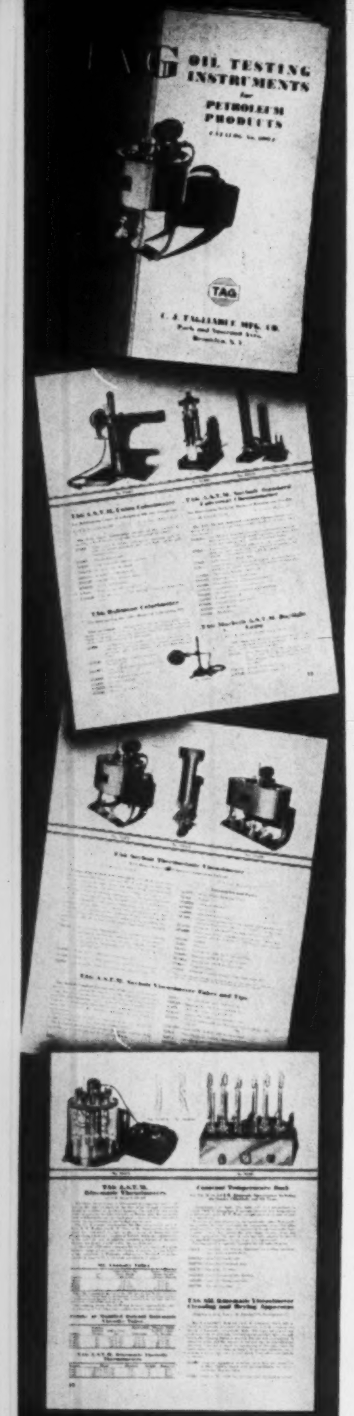

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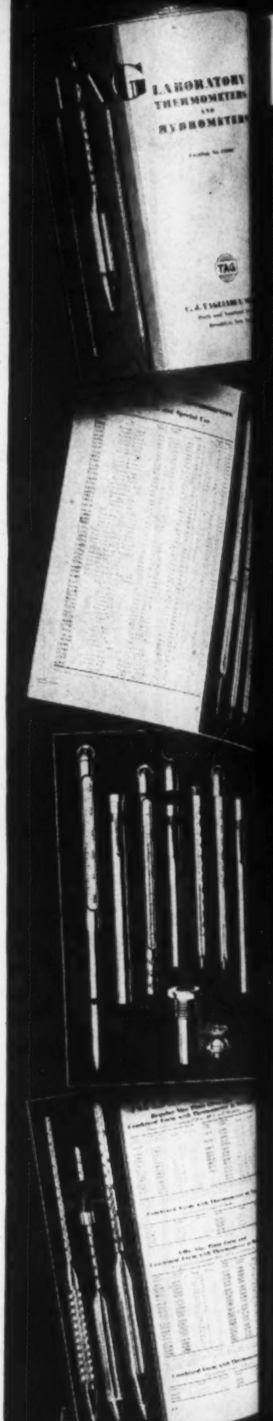

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Instruments

Vol. 16 MAY 1943 No.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

The Kilgore Bill

VARIOUS organizations urge us to support or to attack Senate bill 702 for "scientific mobilization." To us this bill represents the same old anti-technology spirit in a new body. Although the occasion is different we could use any one of several editorials—and indeed we proceed to do so* without changing a word:

"Our enemies—your enemies—seem to have made converts among the advisers of the Administration. . . . The situation at Washington is so complex as to defy analysis. Technological progress has its friends as well as its enemies. . . . Pressure groups waging war on industry . . . seem to have discovered the efficacy of flanking attacks, of undermining. What they demand is 'planning'—which of course means hampering—the advance of technology.

"You know the obvious answers: it would cripple industry to have new methods and new devices passed upon by *any* dictatorial board in Washington. Even a board of geniuses would not have foreseen in 1912 the millions of new jobs created by the new industries in this quarter-century. And *who* is the super-genius capable of selecting the geniuses that will serve as Kommissars of Inventions?

"Yes, you know the answers. But the public doesn't. And the mob hates intelligence. Dangers still impend." —MFB

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*From Sept. 1937 editorial discussing report of National Resources Planning Committee on "Technological Trends and National Policy."

Air Flow Measurements to Engines and Carburetors

To the Editor of *Instruments:*

In Mr. E. H. TenBroeck's letter of March 4, which is reproduced on page 136 of the March issue of *Instruments*, under "Letter to the Editor," the effect of pulsating flow on the accuracy of the manometer indication is discussed, with the implication that this subject should have been included in the article on "Speeding up Air Flow Measurements to Engines and Carburetors," which appeared in the February issue of *Instruments.*

We agree entirely with Mr. TenBroeck's comments as far as the effect of pulsating flow on measuring accuracy is concerned, and the means of reducing pulsations when they exist by installing capacity chambers to permit accurate flow measurement. Likewise, it is quite possible that an ordinary automobile engine will produce pulsations in the intake air supply sufficient to seriously affect the accuracy of a metering system. However, it should be pointed out that the article in question was devoted specifically to the measurement of air flow to engines and carburetors which are now being manufactured for use on aircraft and tanks, and which characteristically do not produce pulsations at the carburetor intake. This is probably due to the carburetor construction employed, which is such as to damp out any pulsations which may have been produced at the engine cylinders.

Since the prime movers used when testing carburetors alone are centrifugal blowers or fans which produce an essentially pulsation-free air supply, there is no possibility of any pulsations existing in a carburetor test cell installation. Likewise, the test results thus obtained are reproduced when the carburetor is assembled to the engine and retested, proving beyond question that the problem of pulsating flow does not exist in the testing systems now being extensively employed.

The fact that pulsations do not exist at the point of primary element installation on carburetor or engine test cells is further evidenced by the very high degree of accuracy obtainable in typical installations and by the fact that the various aircraft engine and carburetor manufacturers, who have been testing these units on a production basis for several years, are able to obtain consistent results using any of the approved air measuring systems.

Cleveland, Ohio BAILEY METER COMPANY
April 15, 1943 By: J. P. GREEN

Remember Pearl Harbor by Helping Hawaiian Readers

To the Editor of *Instruments*

Conditions here, . . . necessary that every shop do its utmost. . . . Our shop has been working almost entirely for the war production for the past two years.

As shop work for aviation has become a large item, we have equipped our shop to handle small precision work. I had years of training in Philadelphia along instrument making and . . . with the necessary information on aviation instruments I can put my shop to good service. . . .

With your contacts, perhaps you could put me in touch with some correspondence school or business which could sell me the information sheets or technical pamphlets . . . that I need. In these islands, we are so far from the center of such information that it is difficult to know where to turn.

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2015 S. King Street, WILLIAM WEINRICH, Pres.
Honolulu, Hawaii, April 27, 1943

EXTRACTS FROM OUR REPLY

. . . We could not conveniently write individual letters to all aircraft instrument schools and aircraft instrument manufacturers. I intend, however, to print an abstract of your letter in our May issue which is about to go to press. The result, no doubt, will be that you will hear directly from a number of schools and aircraft instrument manufacturers. . . .

We have directories of aircraft instrument schools and of aircraft instrument manufacturers, but these directories do not make a special classification of the schools and of the manufacturers who *publish* instrument shop work courses.

Advertisement of such correspondence courses have appeared in *Instruments* and in various aviation magazines. You might look up your *Instruments* file and the files of the various aviation magazines in a technical library—for example, at one of the Army or Navy aviation bases. . . .

A New Resonant-circuit Method of Remote Positioning or Remote Operation

By **DAVID WILLIAM MOORE, Jr.**
Fairchild Aviation Corp., Jamaica, N. Y.

INTRODUCTION

ELECTRIC telemetering, remote-positioning and remote-control equipments have become useful in many industries; they have become *essential* in many types of modern aircraft. The increasing size of planes has complicated the control problem by lengthening the distance between the various control and accessory components, thereby rendering the use of flexible shafts and mechanical linkages impractical. A flexible shaft cannot be relied upon for accurate control adjustments if it is too long, or overloaded, or made to traverse short-radius bends. In many actual instances, it is impossible to design around these limitations. In some planes, moreover, the problem of utilizing available space compels building equipment into a greater number of separate components than is functionally necessary. Each unit must then be capable of proper interaction with its associated units, often requiring the translating of shaft positions from one section to the other. These units, tucked away wherever space is available, can seldom be successfully controlled by mechanical means.

To solve these problems, various electrical positioning and control systems have been developed, the best-known of which is the self-synchronous position repeater.* This device is efficient and accurate for indications which do not require the development of any appreciable amount of torque, the electrical system employed being too elastic for supplying substantial torques with accuracy. Power-producing position-repeating systems have been developed, but many of them require contacts and relays for their operation, rendering them unsatisfactory from the maintenance point of view. Most of these contact-operated controls are of the so-called on-off type and do not produce a control torque proportionate to the input error signal, thereby being susceptible to hunting if adjusted for high sensitivity.

This article describes a simple electrical position-repeating and control system the operation of which is based upon the change in the phase relationship between the current and voltage in a series resonant circuit as the tuning of the resonant circuit is varied. The system sensitivity is a function of the "*Q*" of the resonant circuits employed, and is high for values of "*Q*" which may be easily obtained in normal practice. No electrical contacts are required in any of the circuits, thereby permitting the design of an exceptionally reliable instrument. High-torque low-power operation may be had without any electronic amplifiers. The application of this method to the control of low and substantial amounts of power will be discussed and practical circuits will be proposed. The article will conclude with a brief description of the application of this method to single- and multi-channel radio control.

THEORY OF OPERATION

This system depends for its operation upon the phase characteristics of an electric series resonant circuit.

The series resonant circuit consists of inductance, capacitance and resistance in series, the value of the resistance determining the "*Q*," or efficiency, of the circuit. Fig. 1 shows the current and current-voltage phase relationship as the frequency of the applied voltage is varied above and below the resonant frequency of the electric circuit. The current is maximum and in phase with the voltage when the circuit is tuned to resonate with the frequency of the applied voltage. As the applied-voltage frequency is changed slightly, the electric circuit is no longer tuned to resonance and the phase of the current with respect to the applied voltage shifts rapidly, leading or lagging the voltage, depending upon the direction of the frequency change. This phase shift is rapid to approximately 45° leading or lagging and then asymptotically approaches 90° as the frequency change is continued. The rate of change of this phase shift is a function of the efficiency or "*Q*" of the electric circuits, being greater for more efficient circuits. Since this reso-

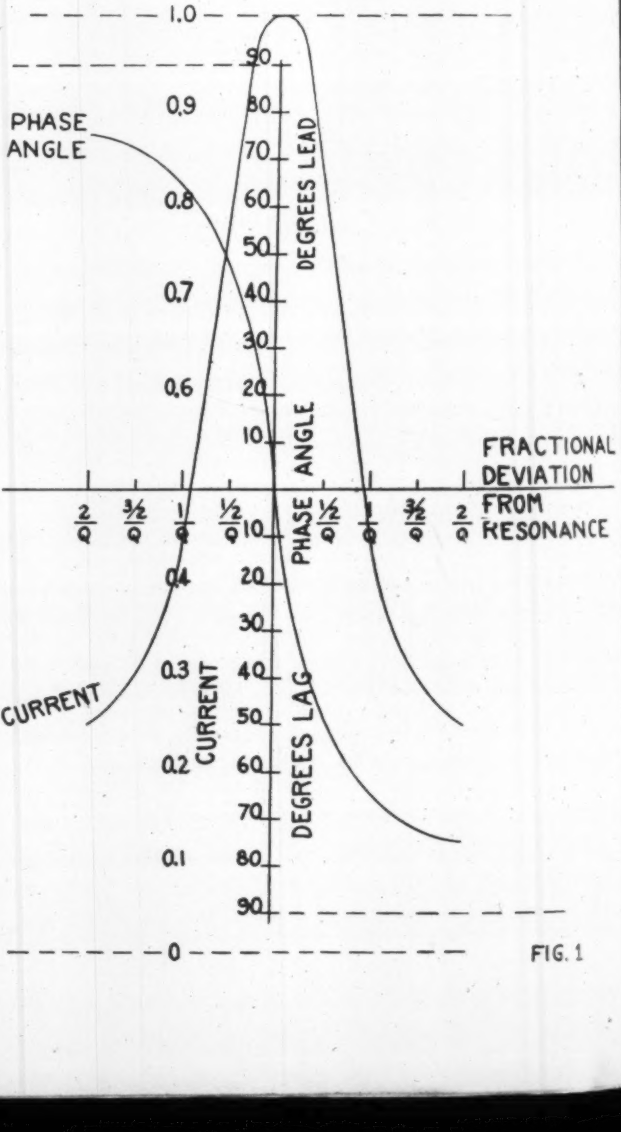

FIG. 1

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*P. A. Borden & M. F. Behar. Position Class Telemetering Systems. *Instruments*, Vol. 8, Dec. 1935, pages 323-332.

nant control system is operated by a phase-sensitive servo, the efficiency of the electrical circuits determines the sensitivity of the control and may be designed to a value consistent with the application and cost of the equipment. In practical resonant control apparatus operating on power frequencies, a *"Q"* of five will permit sensitivities of the order of 0.1% change in frequency or in inductance.

BASIC RESONANT CONTROL

Fig. 2 is a schematic diagram of the basic resonant control system. The phase-sensitive servo used here is the simple two-phase electric motor which has the property of developing torque only when there is an electrical phase difference between the currents in the two phases. Maximum torque is developed when there is an electrical phase difference of 90° between the currents in the two motor phases. The direction of the torque produced depends upon which motor phase has leading current.

The series resonant circuit in this system consists of the mechanically-variable inductances L_1 and L_2, capacitance C_1, and phase 1 of the motor. The position transmitter of this system is inductance L_1 which may be varied by rotating its control shaft. It is connected to the position receiver by two electrical conductors which may be of considerable length. The position-receiving section consists of inductance L_2 which is adjusted by the two-phase servomotor. Phase two of the servomotor is connected directly to the alternating-current power supply, and adjusted to unity power factor by any convenient method, so that the current passing through it is in phase with the applied power supply voltage.

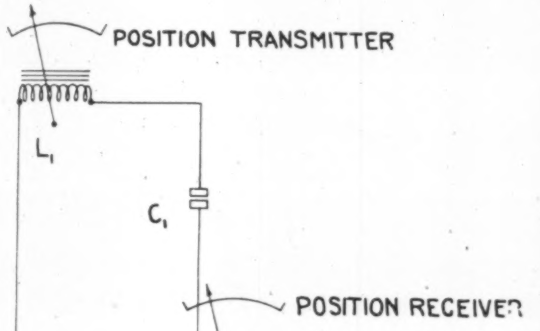

FIG. 2

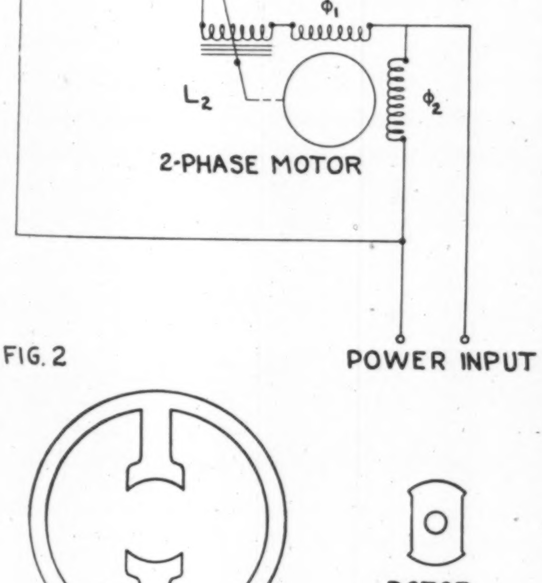

FIG. 3

In the stand-by or equilibrium condition, the series resonant circuit is adjusted to resonate with the applied voltage and in this condition also passes in-phase current. Therefore, the two-phase motor has unity power factor current in each phase; and no torque is developed because there is no electrical phase difference between the currents in the two motor phases. If the position-transmitting inductance L_1 is varied by turning its shaft, the series circuit is slightly detuned, producing a shift in the phase of the current passing through it, which produces an electrical phase difference between the currents in the two phases of the servomotor, causing it to develop torque. This torque is used to turn the control shaft of inductance L_2 in the proper sense to adjust it until the series circuit is resonating with the power supply frequency and equilibrium is again established. The servomotor thus tends at all times to maintain a condition of resonance in the series circuit by maintaining the sum of the inductance values of L_1 and L_2 constant.

To permit accurate and linear position repeating, it is necessary to design the mechanically-variable inductances to change their value linearly with input shaft rotation, and to be complementary units, since the value of the inductance in the position receiver must increase as the value of the position-transmitting inductance decreases to maintain the sum constant. Fig. 3 illustrates the lamination design to produce this type of inductance change and shows its simplicity, there being no moving coils and consequently no need for brushes and slip-rings. This type of inductance is linear for approximately 70° rotation of the control shaft and, throughout this range, accurate position repeating may be obtained. Greater ranges may be had by gearing with no loss in the percentage of accuracy, or by using different inductance design.

The sensitivity of this system is high near the balance point because the current is rising to a maximum at low electrical phase angles, permitting the development of substantial torques although the phase difference between the currents in the two motor phases is small.

CONTROL SYSTEM INSENSITIVE TO FREQUENCY CHANGE

This basic system is suitable for operation on controlled frequency systems such as a 60-cycle industrial power supply, but would be upset by mobile electrical systems where the frequency of the applied voltage may shift several percent. This upsetting is caused by the electrical phase shift in the series resonant circuit produced by the change in frequency of the power supply voltage which has the same effect on the system as the change in phase angle caused by a change in the value of inductance L_1.

A system has been devised which is independent of reasonable changes in frequency. This system, Fig. 4, consists of the basic resonant control circuit with a second series resonant circuit added in phase two of the two-phase servomotor. The position transmitter in this frequency-insensitive system consists of inductances L_1 and L_3 which are mounted in the same case and varied by the same shaft. They are mechanically arranged so that as the value of inductance L_1 is increasing, the value of inductance L_3 is decreasing. This produces opposite electrical phase shifts in the two resonant circuits, with a resulting electrical phase difference in the servomotor, causing motor torque which adjusts inductances L_2 and L_4 (designed to be complementary to L_1 and L_3) until resonance is re-established. The sensitivity of this system is greater than that of the basic system since two series resonant circuits are being detuned, doubling the phase difference in the servomotor for a given inductance change. If the electric power supply exciting this system shifts in frequency, each series resonant circuit is affected in the same manner, producing equal phase shifts in the same direction in each circuit causing no electrical phase difference between the currents in the two motor phases. Consequently, this frequency change does not affect the zero or balance point of the system. A system of this type will tolerate a frequency shift of 8% with no serious effect on its operation. Higher frequency shifts do not cause a change in the zero position but are accompanied by serious torque reduction.

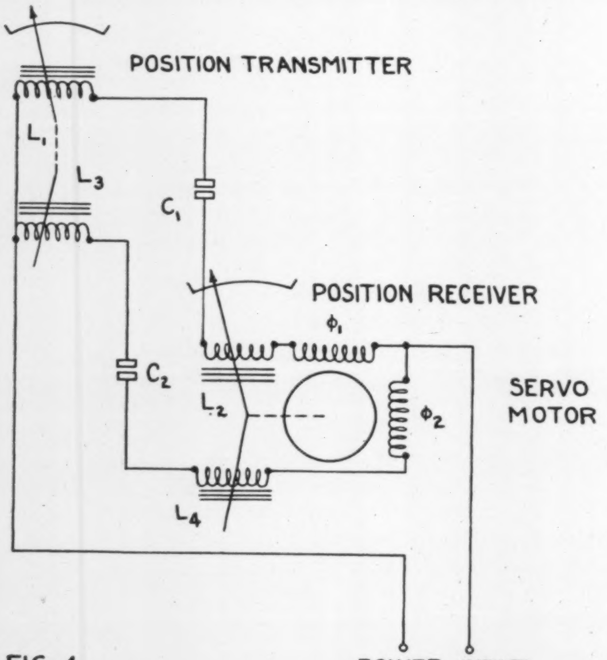

FIG. 4

PRACTICAL CONTROL SYSTEM

A practical follow-up system has been constructed in accord with the principle just described. This unit operates from 110 volts at 60 cycles, drawing a maximum power of 14 watts. The torque output is at least 50 inch ounces per degree error between the position-transmitting shaft and the position-receiving shaft, with a maximum torque output of approximately 30 inch pounds at 10° error. This unit tracks the position transmitter within 1% and is sensitive to at least 0.5% change of the maximum angular range. This particular unit has been designed for operation on both 50 and 60 cycles, the value of the resonating capacitors being changed by means of a toggle switch to insure maximum efficiency on both frequencies.

HIGH POWER OUTPUT

These position-repeating systems are limited in power output since the maximum current drain is in the standby, or equilibrium, position. After the maximum allowable standby current is reached by a system of this type, greater torques and higher power may be obtained by using phase-sensitive servos different from the two-phase motor. Thyratron tubes are logical servos since they require little control power for large controlled power. Using these tubes as phase-sensitive servos, large powers may be controlled with moderate-size inductances and capacitances.

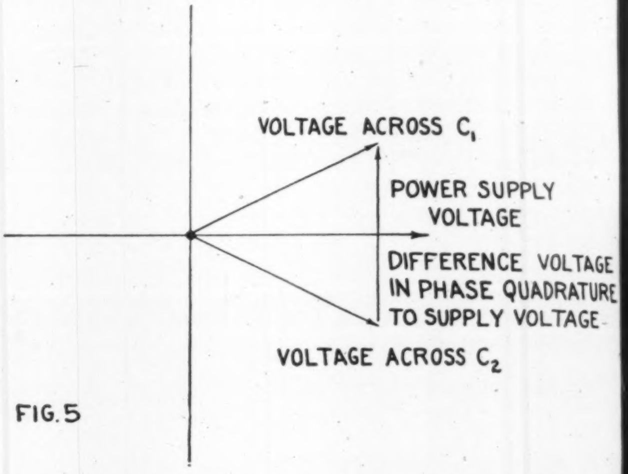

FIG. 5

If the difference between the voltages across two series resonant circuit capacitances, as shown in the vector diagram, Fig. 5, is used to control the thyratron grids, the electrical phase of this voltage will always be the optimum angle for firing the tubes. The phase of this difference voltage, as shown in the vector diagram, does not change with the changing phase of the series currents, but is either leading or lagging the electrical supply voltage by 90°, depending upon the phase characteristics of the two circuits, and may consequently be utilized to fire either one of two thyratrons to control a suitable servomotor.

Air or hydraulic servos may also be used if desired. A direct two-phase motor resonant control system may be used to operate the servo valve, the servo adjusting the follow-up inductance and the mechanism to be controlled. Large powers may easily be handled in this manner with rapid action. Hydraulic power "metered" by this system could be used for the positive positioning of control surfaces on large aircraft—and for numerous purposes in industrial plants.

TORQUE-AMPLIFYING SYSTEM

Fig. 6 shows a torque-amplifying system suitable for transmitting a low-torque shaft position to an adjacent shaft with increased torque. The resonant control system is the frequency-insensitive circuit

Concluded on page 280

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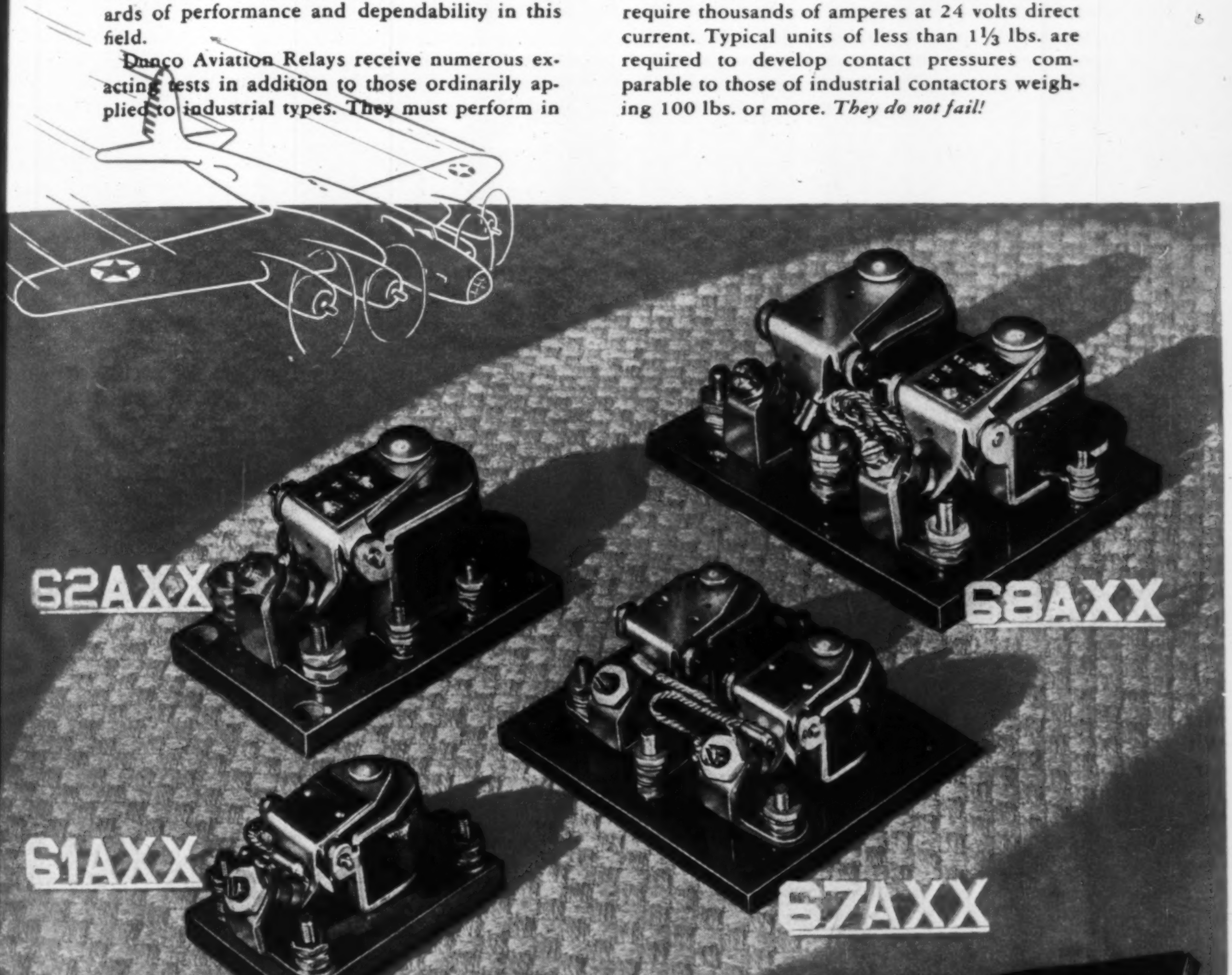

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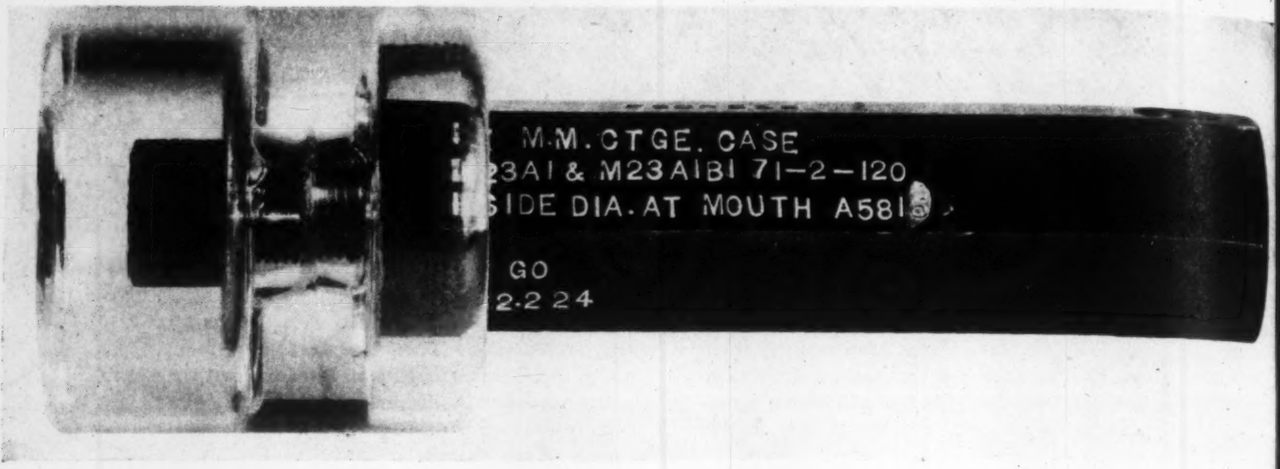

Fig. 1. The VERY newest! Photograph taken in April 1943 at Frankford Arsenal, of a glass plug gage of the latest type with Trilock handle, for checking inside mouth diameter of 57 mm. cartridge case. (Actual size.)

Newest Developments in Glass Gages*

By Colonel H. B. HAMBLETON, Ord. Dept., U. S. Army

Chief of Gage Section, Ord. Dept., U. S. Army, Washington

IN July 1942 the glass gage project started when we discovered that the A. H. Heisey Co. of Newark, Ohio, had experimentally produced a few glass gages made from some old glass candlesticks, for a concern in the Middle West. This company produced glass gages for our use and, after considerable experimental work, we decided that this project was worth following and appeared to have enough value to warrant the concentrated energy of several glass manufacturers. About this same time, the Corning Glass Works of Corning, N. Y., and the T. C. Wheaton Co. of Millville, N. J., became interested in glass gages and the Ordnance Department requested them to give it the benefit of their long experience in glass technique. These outstanding glass producers have given us their wholehearted coöperation.

Glass is "something new" to the gage industry and gage users. Gages are "something new" for the glass industry. With this in mind, we must expect problems during the early stages of the conversion effort. It is not so many years ago that steel was a problem to the gage industry. Many gage users of the last war and the following decade will recall the problems of cracked gages and dimensional instability resulting from insufficient metallurgical research on steels and their heat treatment for gages. The problems of steel for gages were overcome by research and development carried on between the gage industry and the steel industry.

During the twenties, considerable research was carried on to determine the steels best suited to provide adequate gage wear life. In this war, we must have similar coördination on research and development between the glass industry and the gage industry to insure the success of the glass gage conservation effort. A few "doubting Thomases" scoff at the glass gage effort because of the relatively small steel savings that will result. To them we can only say that the sum of a number of small contributions will result in a sufficient major contribution to steel conservation that will enable us to renew production of armament that is now hindered by steel shortages. Armies are made up of individual men who each contributes his bit. Small contributions must be made in conservation as well as everything else to insure our victory in this war.

Substitution for conservation by the Ordnance Department has in many cases opened new horizons in the engineering field itself. Many of our substitutes have been found to be superior to the materials originally specified. We are confident that our glass gage effort will result in new horizons for the gage industry and gage users.

In the glass industry a process now in use forms glass to extremely close tolerances on internal functions such as holes and tapers. This process requires an extremely accurate mandrel on which the glass is shrunk or molded. We in Ordnance have many special gages that are not normally used in commercial manufacture, examples being chamber and ogive gages for ammunition, involving extremely close-toleranced internal tapers or curved contours. The glass industry is now working on the development of manufacture of chamber and ogive gages by this "precision shrinking process." If no results other than this development were successful in the glass gage effort, all the time and energy spent on this project would be justified. However, we are confident that other "new horizons" than the precision shrinking process will be opened by the glass gage effort and some clues to these horizons would probably include cheaper gages and the release of critical machine tool capacity.

It might be apropos at this time to point out some of the advantages of glass gages: (1) Many greasings and degreasings are eliminated; (2) perspiration of the inspector's hands has no corrosive effect; (3) scratches on glass do not raise a burr or change the effective size of the gage; (4) the thermal conductivity of glass is low and heat transferred from the inspector's hand will not affect the gaging dimensions; (5) glass is approximately one-third the weight of steel and several types of gages which are now made solid will be hollow when made of glass, which will obviously make the glass gage much lighter and more advantageous to use.

In every new development, there is a tendency to put the new product to the "toughest" tests. In Ordnance we have given glass gages a "tough" test on gaging cartridge case mouth diameters and we are very enthused over the results. The Frankford Arsenal cartridge case shop has used a glass gage for the inspection of 57-mm. cartridge cases. This gage (see Figs. 2 and 4) performed 260,000 gaging operations before it was worn out and for the first 160,000 operations the wear was only 0.00005 inch. A steel gage for this ame duty normally has a life of 60 to 70 thousand operaions. At the present time, the Ordnance Department has everal glass gages under test and the results of these ests will be made public within the next month.

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*Substance of a talk before the American Society of Mechanical Engineers, Spring Meeting, Davenport, Iowa, April 28, 1943.

Outside of Ordnance we have heard of some "tough" test f glass gages on extremely close toleranced functions here even chrome-plated steel gages do not "stand the aff". With little development yet accomplished on glass ompositions and treatments, we must expect some of the irst glass gages to fall by the wayside, but if the research nd development that has been put into chrome-plated ages had been put into the development of glass comositions and treatments, the performance of glass in closeolerance applications would probably have been more avorable. In all close-tolerance gaging functions, the rubbing of the gage during each application creates a serious ear problem. Fortunately in Ordnance we are not bothered ith many close-toleranced gaging functions, because for ears we have had an effective gaging policy that quickly liminates close tolerances where they are not necessary. Our experience has been that rigid adherence by effective gaging to drawing requirements usually results in liberalized tolerances. Because of our Ordnance drawing tolerances we are not much disturbed about the failure of a few glass gages on close-toleranced applications.

In every new mechanical venture, new "bugs" develop that must be overcome by research and development. Pioneering in a new development requires fortification against the satisfied few. Many will recall the strenuous objections to four-wheel brakes and steel bodies in the automotive industry. We must not let the "satisfied few" stand as an obstacle to the success of the glass gage effort or any other progressive engineering development.

While more or less in the experimental stage for the last six months, with much yet to be learned, we are convinced from our experience at Frankford Arsenal that glass gages have possibilities and are so efficient that we fully expect them to become a permanent fixture in the industrial world after this war. You may also be surprised to know that surface plates made of glass are commercially obtainable.

Glass gages in sizes under 3/8" are difficult to produce and will probably never be commercially made. However, synthetic sapphires, synthetic rubies and other synthetic jewels, with considerable resistance to breakage, with a hardness which will readily scratch the toughest glass, are being produced by the Linde Air Products Co. and have been extensively used by the Hamilton Watch Co. The only discernible difference between synthetic sapphires and rubies and the natural gems is the grain structure, which is detectable only under a microscope.

The approximate cost of these synthetic jewels, which are produced in rods, would be in the neighborhood of 20c per inch, furnished in sections approximately 8" to 10" long. Single crystals are also produced approximately ¾" in diameter and 2" long, which in the case of the sapphire and ruby must be split in two, because of internal stresses.

Frankford Arsenal has procured acceptable glass gages from the Corning Glass Works, Corning, N. Y., Fisher and Porter Co., Hatboro, Pa., the A. H. Heisey Co., Newark, Ohio, T. C. Wheaton Co., Millville, N. J., Specialty Glass Co., Newfield, N. J., and the Blue Ridge Glass Corp., Kingsport, Tenn. An interesting development is the flat snap gage produced by the Blue Ridge Corp. This gage is made from one of their standard plate glasses and will stand considerable abuse. While most glass companies are now producing gage blanks, the Ordnance Gage Co., Philadelphia, Pa., Turner Gage Grinding Co., Detroit, Mich., Abdite Gage Co., Dearborn, Mich. and Langlois Gage Co., Detroit, Mich., have marketed finished glass gages and report satisfactory results by users.

One of the questions raised by the use of a new material is whether there is a method of measuring the hardness of glass comparable to the well-established methods used on metals. Indices showing the scratch hardness of certain types of glass have been set up and the National Bureau of Standards has developed a method known as the Knoop

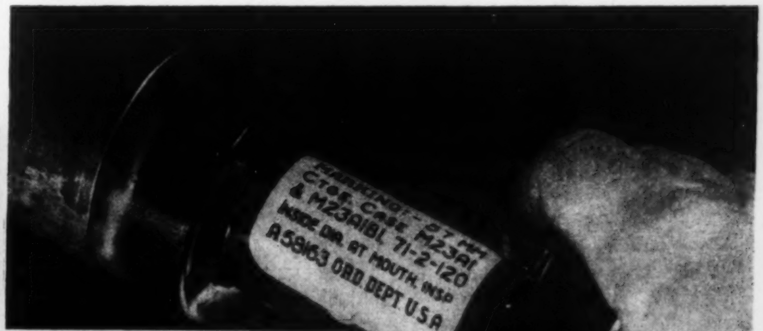

Fig. 4. Close-up of the gage shown in Fig. 2. (Made by T. C. Wheaton Co.)

Official OWI photo by Hollem

Fig. 2. Gaging the inside diameter of the mouth of a 57 mm. cartridge case at Frankford Arsenal with a glass gage which performed 260,000 gaging operations before wearing out.

Official OWI photo by Hollem

Fig. 3. Messrs. A. E. Smith and Stanley Farrow of Gage Section, Ordnance Department.

Official OWI photo by Palmer

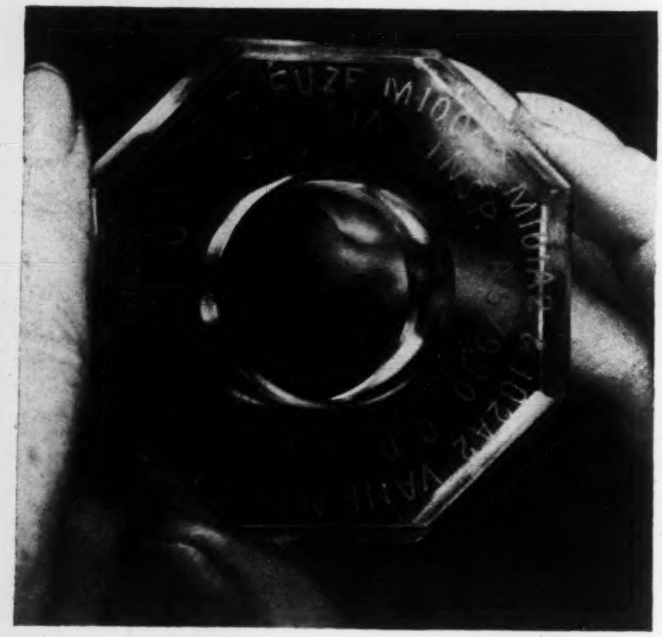

Fig. 5. Shown here in actual size is one of the newest glass ring gages (produced by Heisey Glass Co.) for inspection of fuze parts.
Official OWI photo by Hollem

Indenter* which has been used for measuring the hardness of glass. The question of hardness may not directly be a factor in the wear of glass gages and it is our belief that the finish on the gage will be the greatest factor in its wear. We further believe that one of the glass producers will, by research, provide a harder or tougher glass which, combined with a better surface finish, will materially increase the wear life of glass gages.

The question of standard drawings and specifications is also recurring. To answer this, may I say that Frankford Arsenal, with the aid of the more progressive glass manufacturers in this country, has formulated tentative specifications and provisional standard drawings of glass gages. These standards will, insofar as possible, be dimensionally the same as those of the American Gage Design Standard, shown in publication CS8-41 of the National Bureau of Standards.

It will be remembered by those in the gage making industry that this standardization of steel gages, which was formulated before the war with their aid, has insured complete coördination and interchangeability of all gage parts manufactured during this emergency, and I know they will agree with me that this standardization has eliminated a great deal of confusion that would have existed had this work not been completed.

Both the Corning Glass Works and the T. C. Wheaton Co. have been experimenting with the grinding and finishing of glass gages. These two outstanding glass producers have arrived at practically the same conclusions. I will quote data on the three most important considerations in grinding of glass, viz., grit, bond and surface speed, as recently furnished me by Mr. Thompson of the Corning Glass Works.

GRIT: The work to date permits definite conclusions concerning the grit for rough finishing: this can be 50 or 60. But, for the final finishing, much work remains to be done. We know, however, that a very smooth surface is obtainable with 150 grit wheels, but only when the coolant is shut off during the final passes, when the depth of material being removed is of the order of 0.0001" per pass. The glossy finish thus obtained is the result of slight surface-glazing of the glass due to the frictional heat developed. Although we have not as yet obtained delivery of the grinding equipment which will enable us to thoroughly study the over-all problem in all its aspects, our accumulated experience on gage finishing and other glass finishing operations leads us to believe that further improvements can be made by resorting to wheels of considerably finer grit.

BOND: Until we are able to accumulate evidence to the contrary, we believe that "soft" vitreous bonds are most nearly foolproof for glass finishing despite the fact that they are definitely weaker mechanically. As regards the latter, we have been assured by abrasive wheel manufacturers that even the softest bonds can be made strong enough to eliminate any possibility of personal hazard when the wheels are properly used.

SURFACE SPEED: I have gathered the impression from numerous contacts with gage makers that they are somewhat worried about the problems involved in adjusting speed of their present machines, which were designed for work on steel, to other speeds which would presumably be better adapted to glass grinding. The further we get into the glass gage business, the more we are inclined to believe that speed is a relatively secondary problem and that there may be no necessity for alteration of the driving mechanism of existing machines.

It may be recalled that, initially, when we reported on our accumulated experience in glass grinding, we stated that our best results have been obtained with surface speeds of 2500 f.p.m. or less. This is still essentially true, but it must be remembered that our machines have been specially fitted for glass grinding only.

Much of the "mystery" of glass grinding is being dissipated by continued application of the principles of research. The wheel-speed problem seems to be simmering down to a relatively simple problem in thermodynamics. All glasses are, of course, much less conductive of heat than metals; in fact, this is one of the advantages for glass as a gage material. But, correspondingly, this also means that the heat generated in the grinding operation tends to be stored up in a shallow depth of the glass gage. This, in turn, paves the way for "rather severe thermal strain" and, if the latter becomes excessive, there is possibility of thermal breakage or "checking" of the blank while it is being ground. Obviously, the answer is to remove the heat of grinding as rapidly as it is generated, or, in other words, balancing heat input and heat removal. In general, the quantity of heat generated will be a function of the wheel speed and the depth of cut; and the rate of removal will be, to a large extent, determined by the quantity and distribution of coolant. It follows that when the flow and distribution of the coolant is reasonably well standardized, there remain only two variables, both of which are subject to control, namely, depth of cut and surface speed. Accordingly, if the surface speed is high, that is, approximately 6000 s.f.m., which is conventional for steel grinding, the heat input can be correspondingly reduced by reducing the depth of cut. Therefore, there need be no alteration in speed of existing machines in order to grind glass satisfactorily. It is simply a question of finding the best combination of bond and grit of wheels to produce the most highly polished finish. On this point, we expect to have rather specific information available within a reasonably short time after the equipment being made available to us is placed in operation. From present indications, this will be a matter of about six weeks. Oddly enough, our biggest bottleneck now is getting delivery of the desired assortment of grinding wheels for this purpose.

In regard to the coolant required for grinding glass, they have found from experience that plain water is all that is required. However, it is necessary to provide some agent to prevent rust on the machine; for this, they have used International Chemical Co.'s No. 219 oil, diluted 25 to 1.

In using the taper lock handle, it will not be necessary to grind the taper on the glass shank as this can be molded close enough to give the required fit.

Continued on page 302

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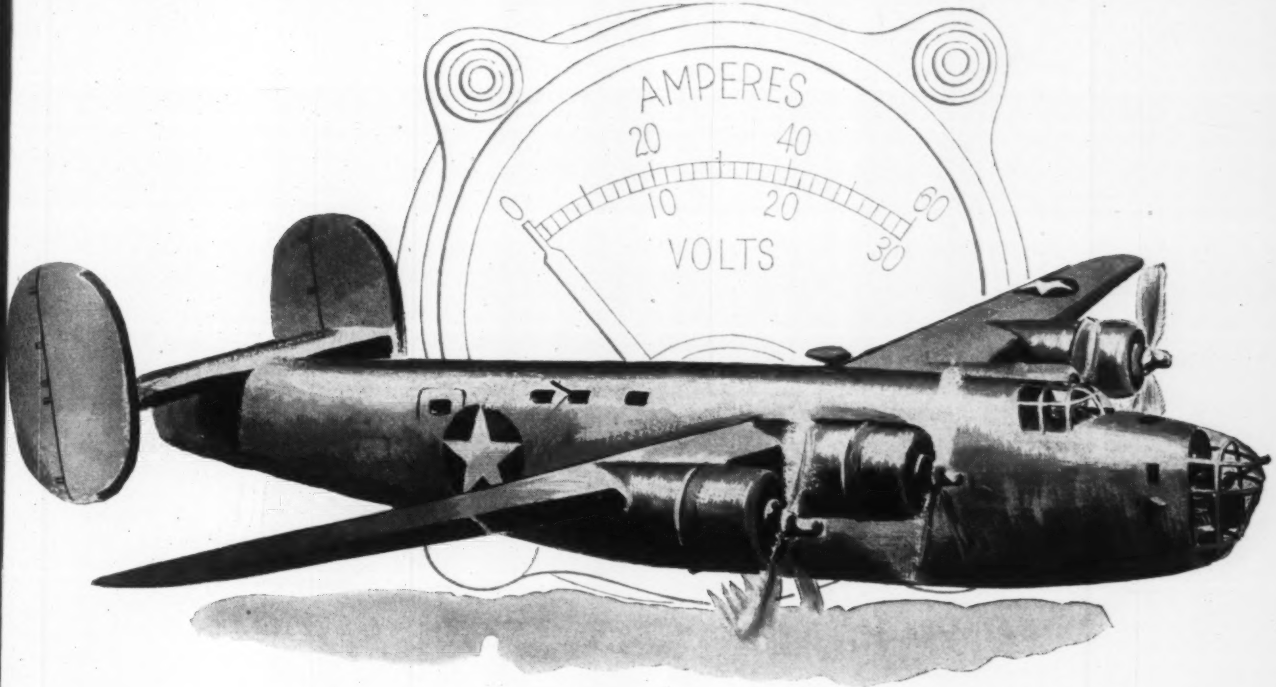
*F. Knoop, C. G. Peters and W. B. Emerson. "A Sensitive Pyramidal Diamond Tool for Indentation Measurements." *National Bureau of Standards Journal of Research*, Vol 23, 1939, pages 39-61. (Reprint: *Research Paper No. 1220*).



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ELECTRON TUBES

Their Principles and Their Instrumentation Applications

By **ANDREW W. KRAMER**
Managing Editor, *Power Plant Engineering*, Chicago, Ill.

CHAPTER I

IN the thirty-odd years since it was discovered, the electron tube has grown from a mysterious delicate scientific toy into the most powerful and all-important single device in the world. By its aid we talk across the seven seas. It enables us to see into germ structure—or through dense fog to guide our airplanes in their flight. It provides us with the most delicate means of measurement and gives us control over the most infinitesimal forces as well as the greatest we have been able to produce.

Despite its common use, the electron tube is still regarded by many as a mysterious and complex device. Actually the electron tube in its fundamental character is no more difficult to understand than is the operation of a switch; indeed, as has been shown in recent years, the action of a switch in opening an electric circuit is an extremely complex thing and its understanding involves greater knowledge of the physics of electrons and atoms than does the operation of the electron tube. Reduced to its fundamentals, the electron tube is a simple device and its operation can readily be grasped by an intelligent child of twelve if properly explained.

In trying to understand the electron tube we must not associate it with the mystery of radio. The vacuum tube does not enter into the mystery of electromagnetic radiation through space, no more indeed than does any other electrical device. The transmission of a person's voice to the far corners of the world requires not only electron tubes but also generators, batteries, resistors, capacitors, relays, switches and countless other electrical devices with which all engineers are familiar and the electron tube should not be considered more mysterious than any of these devices.

Nor must the electron tube be thought of as a delicate, fragile device, not suitable for industrial use. Even the tubes in our radio receivers are extremely rugged devices, many indeed are of all-metal construction. For industrial instrumentation purposes their ruggedness compares favorably with most other electrical equipment, and in operation and maintenance they are in many ways superior. In many applications, tubes are in continuous service 24 hours a day, seven days a week, 52 weeks a year. In fact, tubes in such service often show a longer life than those used in intermittent service. Tubes have been recovered from the wreckage of airplane crashes, intact in every detail and suitable for re-use. Modern tubes rarely burn out; they may fail from loss of emission or from deterioration of the vacuum but seldom does the heater element burn out when used at rated voltages.

It is true that the study of electron tubes (when they are considered in their complex forms and associated with intricate circuits) takes on all the difficulties and complexities that characterize the *advanced* study of *any* subject; but its fundamentals are just as easy to grasp as are those of an electric motor, in fact, they are simpler. They are simpler because in the electron tube we are dealing with electricity in its elemental form—with electrons and protons.

In a certain sense this is true of other electrical equipment as well because electricity, regardless of how or where we encounter it, is composed of electrons. That which we call an electric current is nothing more than a stream of small negatively charged particles called electrons. Only in the electron tube, however, do we have the opportunity of studying these electrons apart from matter and that fact, more than anything else, perhaps, gives the electron tube the unique and useful properties it has.

Now, what is there that is so remarkable about the electron tube? In outward appearance, as we are familiar with it in our radio receiver, it appears little different from an ordinary incandescent lamp except that it gives only a feeble light. It is constructed of glass and metal parts and the fact that it is evacuated should not make it remarkable, for lamps have been evacuated for years. Furthermore, its structure, at least in the simpler forms, is less complicated than that of a thermostat. Fundamentally the electron tube consists of an incandescent filament and a metal plate mounted inside an evacuated glass or metal envelope. The plate usually is connected to the positive terminal of a battery or generator and the filament to the negative terminal. Thus the filament is called the cathode and the plate the anode. Under such conditions, current flows in the circuit, the current evidently passing across the intervening space between the filament and the plate.

It is this last feature which gives the electron tube its remarkable properties—the fact that a current of electricity is able to pass across empty space. What is the explanation of this action? And why is an incandescent filament necessary? For it can be shown that the instant the filament cools the current ceases, though the potential across the terminals remains as high as when the filament was heated, or higher.

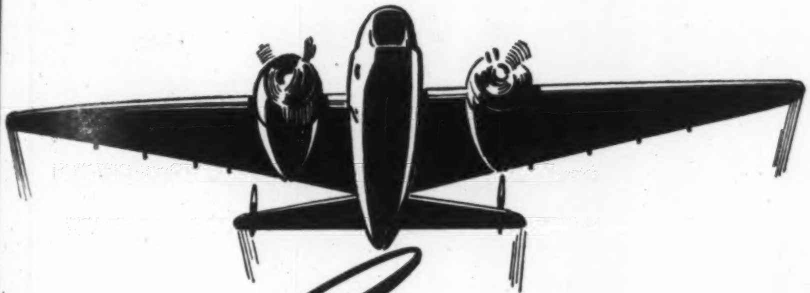
It is the purpose of this serial to attempt to answer these questions—to describe simply and directly the action of and the principles upon which the electron tube operates.

Since an understanding of the electron tube can only be obtained if we understand something of the fundamental nature of electricity and matter, before we begin to discuss the electron tube itself, it will be to our advantage to consider briefly the nature of electricity and its relation to matter.

HERE it is at last—the serial you want. Of all subscribers' suggestions, the most insistent have been for more articles on electron tubes in Industrial Instrumentation. It did us no good to recommend special magazines and textbooks: they insisted there was no book written for them—for you. So here is the start of it. Mr. Kramer's long experience has included designing and applying electronic instruments.

To begin with, it must be clearly understood that electrons are not in themselves a source of energy any more than molecules of water or air. Like molecules of water or air, electrons may acquire potential or kinetic energy and thus be used to store or transmit energy. They can act as "carriers" of energy and in that capacity they are sent over wires to far distant points. Electricity (and by the term electricity we mean a stream of electrons or protons) flows through or in wires just as water and air flow through pipes. This raises the question, where does the electricity used to transmit power in this manner come from originally?

When water is used to transmit mechanical energy from one place to another, in addition to suitable pumps, water motors and connecting pipes, a supply of water is required. This is drawn from a reservoir or from the city mains and forced into the system. Once the system is filled, no more water is necessary (if there is no leakage) since the amount contained in the system is used over and over again. The pump forces the water through the pipe line to the distant water motor or turbine, driving it, after which the water returns to the pump suction through return lines. No water is lost. (With a compressed air system the action is similar except that in this case the air is not usually returned to the compressor by return pipe lines: air is merely drawn from the atmosphere by the air compressor at one end of

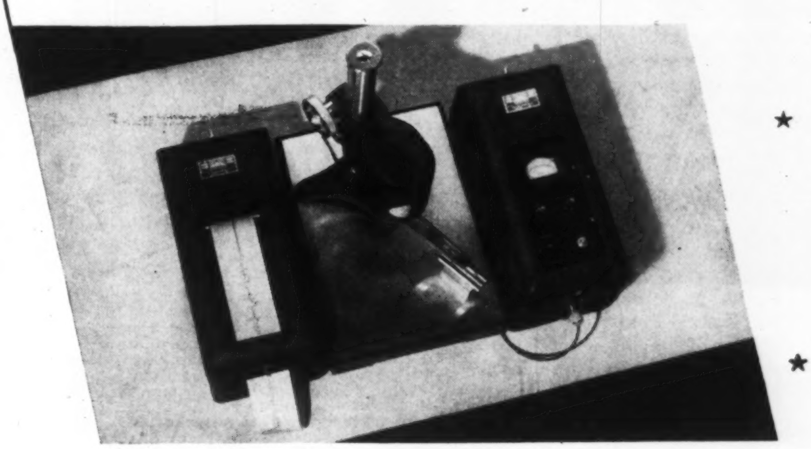


Correction-

● "American industry will produce 5000 planes a month in '43"—this was said in '42.

A correction is in order. It's May, the fifth month of '43, and already we've bettered this estimate by 500 planes a month. Every 7.8 minutes, night and day, a superbomber, transport, fighter or trainer rolls by, props spinning, bound for battle. This correction is proof enough that our Axis opponents are headed for trouble ... Yankee trouble.

It takes tools to build this trouble ... tools that work fast and long, that probe into the vitals of engines to detect harmful vibrations, stresses and strains or reveal invisible irregularities in polished bearing surfaces. Such conditions as these are continually being studied from the chart recordings of the Brush Direct Inking Oscillograph and the Brush Surface Analyzer.



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the system and discharged back into the atmosphere at the receiving end.)

An electric power system having a generator at one end and a motor at the other end is like the hydraulic system. The generator may be considered as a pump used to pump electricity through the circuit. In this case, however, there is an essential difference: it is not necessary to fill the circuit with electricity when it is first set up. Why is this? Where does the electricity in the circuit come from?

The answer is that the electricity is in the circuit to begin with—an integral part of the structure of the material of which the circuit is made. It exists inherently in the conductors as electrons which are not permanently attached to atoms of matter.[1] All matter, regardless of the form in which we find it, is composed of atoms. All atoms consist of a central dense core called the nucleus, about which one or more particles called electrons revolve like a miniature solar system. As do the planets, the electrons revolve about the nucleus in definite orbits. The nucleus carries a positive electric charge and the electrons all carry negative charges. In the normal atom, the sum of the negative charges of all the electrons is exactly equal to the positive charge of the nucleus. Thus the normal atom, considered as a whole, has no surplus of either charge and is electrically neutral.

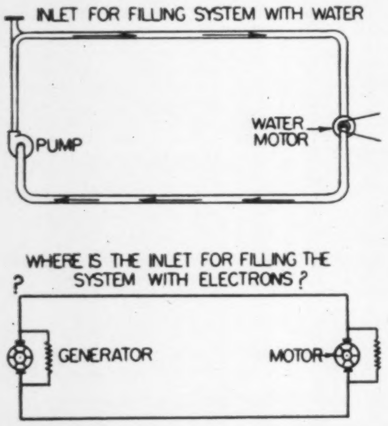
INLET FOR FILLING SYSTEM WITH WATER
WATER MOTOR
PUMP
WHERE IS THE INLET FOR FILLING THE SYSTEM WITH ELECTRONS ?
?
GENERATOR
MOTOR

Fig. 1. Electricity is used to transmit energy from one place to another in the same way that water is used for the same purpose in a closed pipe circuit.

The essential difference between atoms of different elements lies in the different values of the positive charge on the core or nucleus. As this positive charge varies from one element to another, the number of orbital electrons in the neutral atoms also varies. But it must be understood that the number of orbital electrons in itself does not alter the chemical nature of the atom. This means that it is perfectly possible to take an atom (in reality a group of atoms) and by rubbing, rub off one or more of the orbital electrons and the atom will then still remain an atom of the substance we started with. It will, however, no longer be a neutral atom and, because some of the electrons have been removed, the combined negative charges of the remaining electrons will no longer balance the positive charge of the nucleus—with the net result that the atom as a whole will exhibit a positive charge. In this state, the atom will tend to attract any free electron that may be in the vicinity.

This is exactly what takes place when a stick of sealing wax or amber is rubbed with a piece of flannel. The wax becomes negatively charged and the flannel positively charged. In the act of rubbing, the friction rubs off some of the electrons from the atoms composing the flannel and leaves them on the surface of the wax. Since the surface atoms or molecules (a molecule is a group of atoms) of the flannel are left deficient in electrons and the surface atoms of the wax with an excess, if the wax and the flannel are left together after being rubbed there will be a readjustment of electrons, the excess of the wax returning to the deficient atoms of the flannel.

With this picture of the atom in mind we can consider the "free" electron. Most of the electrons in the universe exist as component parts of atoms as described but it is possible for an electron to exist in the free state apart from the atom, temporarily at least. Such free electrons exist everywhere to some extent, in gases, in liquids and in solids, but they are much more plentiful in some substances than in others.

Metals, for example, contain enormous quantities of them while substances such as glass and rubber contain only small amounts. It is the presence of these free electrons in substances that enables us to account for the conduction of electricity. The more free electrons a substance contains, the better conductor of electricity it is. Because of the enormous numbers of free electrons in metals, metals are good conductors of electricity. Substances such as glass, rubber, porcelain, mica, etc., on the other hand, with comparatively small numbers of free electrons are poor conductors of electricity—good insulators.

These free electrons are in constant motion, bouncing back and forth, colliding with one another and with the atoms in the most random fashion. This motion is due to the natural agitation of the atoms and molecules of any substance at normal and high temperatures. The higher the temperature of a substance, the higher the speeds and the more violent the motion of the atoms and electrons.[2]

The motion of the electrons is random. If, however, by some means we can control this random direction we have what we call an electric current. Such a means of controlling or directing the electron motion is provided by an electric generator or battery.

Now we can understand better the analogy between the hydraulic transmission system and the electric system presented in a foregoing paragraph. The electricity needed for effecting the transmission of energy is contained in the metallic conductors forming the circuit in the form of these free electrons. By properly supporting these conductors on materials not having many free electrons, a path is provided over which these electrons can be directed, just as pipes provide a path for the flow of water. It is fortunate that air contains so few free electrons for otherwise it would be difficult to prevent the free electrons in a conductor from flowing out where we do not want them.

Having such an electric "circuit," the question may be asked, "How are these electrons forced through the conductor? How are they set in motion?" We have said that this may be accomplished by a generator, but in what manner? In the case of the hydraulic system the pump piston traps a certain amount of water in an enclosed space (the pump cylinder), then, by forcing this piston down (decreasing the volume) the entrapped water is forced into the discharge line. At the same time the water on the suction side is forced into the space behind the piston. Thus a circulation is established.

The action in the electrical system is similar. The generator, as was indicated, may be considered in the nature of a pump. The piston, in this case, is not a tangible thing but an electric field. It can be shown that when an electron is placed in an electric field, its own field[3] reacts with the

Continued on page 300

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[1] For a more complete explanation of the structure of matter and the nature of electricity the reader is referred to the author's book "Electricity—What It Is and How It Acts," Vols. I and II, but the brief description presented here is sufficient for an understanding of electron tube action.

[2] When we say that free electrons exist in a substance we must qualify the statement by an explanation of the term free electron. The term mobile electron probably would be more correct. In the close packing and random motion of the atoms of a metal, an outer electron of one atom is often brought within the influence of a neighboring atom. If such an atom is held rather loosely or if the attractive force of the neighboring atom is great enough, the electron will leave the first atom and go to the second. While this transition is in progress, the electron is more or less free to be acted upon by other forces and so is called a "free" electron. The result of this continual interchange, brought about by the incessant vibration of the atoms, is a vast number of free electrons in the metal, moving in all directions at high speeds. If an electromotive force be applied to the metal the direction of motion will no longer be completely random for the electrons will be given a drift velocity in the direction of the positive terminal. This flow of electrons constitutes the electric current.

[3] Having an electric charge, every electron is of course surrounded by an electric field of force.

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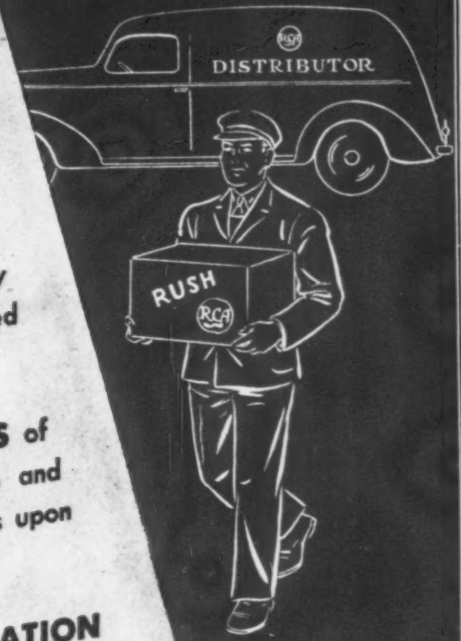

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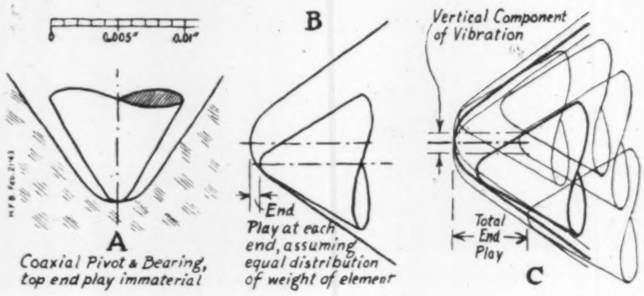
ONE of the most dramatic stories of American ingenuity is like the conquest of a germ disease—a BIG problem affecting millions but involving SMALL things. It cannot yet be told in full because its happy ending" is "certain" but not "in sight"; because the history is being made at this very time; and because those who are making history are modest workers unknown to their millions of beneficiaries. The problem is one of engineering's "toughies" involving many interdependent factors—just as in the science of immunology. It cannot be stated in a few simple words. Part of it is pictured here. When it is solved, its conquerors will not get one millionth of the glory showered on microbe-tamers although they are, in a sense, the tamers of surface molecules, the vanquishers of mechanism's deadliest enemies, Friction and Corrosion. —MFB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0.01"
M F B. Feb. 21-43
A
Coaxial Pivot & Bearing, top end play immaterial
B
End
Play at each end, assuming equal distribution of weight of element
Vertical Component of Vibration
Total End Play
C

In the Laboratory

In the PLANT

In the WAR!

Instrument Pivots and Bearings Go to War

By M. F. BEHAR

PART ONE (FOR THE HOME FRONT)

I. War's Three Requirements

(1) Sensitivity and accuracy; (2) Severe service; (3) Greatly increased production.

II. Implications of Requirements

Industrial solutions of problems are not always applicable to military service conditions; New solutions necessary to obviate need for excessive maintenance and replacements.

III. Questions Raised by War

Reasons for small contact surfaces, for conventional design and for old materials are partly technical and partly human. Other designs and materials not excluded.

IV. Present Situation

1. New trends in research
2. Pivot materials
   (a) Steel; (b) Non-corrosive alloys.
3. Bearing materials
   (a) Diamond; (b) Natural sapphire; (c) Synthetic sapphire; (d) Non-corrosive alloys; (e) Glass.
4. Non-interchangeability
5. Rolling-contact bearings

V. The Immediate Future

Observations of needs and trends is basis for predictions and adhortations.

PART TWO (FOR MAINTENANCE PERSONNEL)

VI. Cleaning and Inspection

1. Cleaning
2. Inspection of Pivots
3. Inspection and Grading of Jewel Bearings
4. Sensitivity Tests as Pivot and Bearing "Inspections."

VII. Pivot Repair and Replacemen:
(By F. E. WILLIAMSON)

VIII. Effects of Vibrations

PART ONE (FOR THE HOME FRONT)

I. WAR'S THREE REQUIREMENTS

IN the field of instruments, as in many others, modern warfare has caused revolutions in old-established practices and has compelled complete reversals of "final" opinions. Perhaps the most striking verification of this statement is furnished by the almost-unbelievable increase in the instrumentation of American aircraft, seacraft, land vehicles and portable equipments for communications, detection, meteorology and other purposes. We say *American* aircraft, etc., because it is only in our own Armed Forces that there can be found the following unprecedented and unparallelled combination:

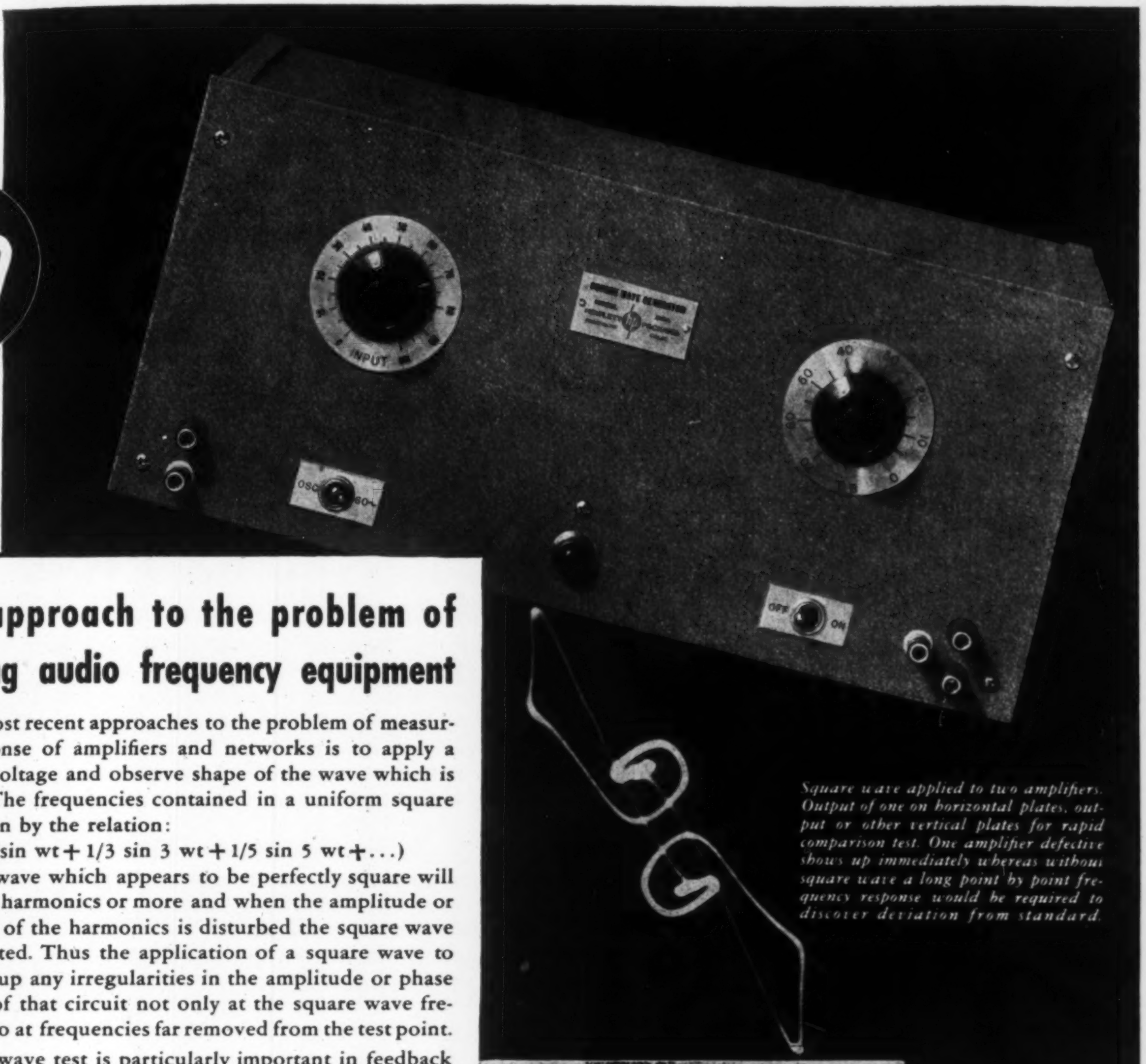
(1) Insistence by Armed Forces procurement agencies upon higher sensitivity and accuracy than characterized the corresponding instruments of 1918. Sensitivity and accuracy go together. An instrument may be designed so scientifically that its maximum design error may be $\pm\frac{1}{2}\%$ of its scale range but if the actual construction of its two pivots and bearings results in a "sticking" effect or insensitivity of 5%, its actual zone of uncertainty will be not less than 10% of its scale range. Today's Army and Navy accuracy tests cannot be passed by automobile dashboard grade instruments; they can only be satisfied by relatively high-grade instruments which yesterday would be considered too delicate for military use.

(2) Application of these sensitive and accurate (hence relatively "delicate") instruments to service conditions far more severe than those of 1918—far more severe, in fact, than the limits beyond which most instrument manufacturers, before 1941, would refuse to guarantee instruments sold to civilian industries. The great majority of these instruments must withstand sustained vibrations which would wear out in a few minutes the delicate pivots and bearings of many pre-1941 switchboard grade instruments. They must withstand gunfire concussions and other sharp shocks which would crack, snap or flatten the bearings and pivots of sensitive pre-war instruments.

(3) Instrumental indications of *all* important measurable conditions affecting the performance of a plane, ship, vehicle or equipment—and of components thereof from the turbines of a battleship to the cells of a "walkie-talkie." The increase, as compared to our last war, is both qualitative and quantitative. The increase is qualitative in that any major unit (an airplane engine, for example) has five to ten times as many of its operating conditions measured as were measured in late 1918. The increase is quantitative in that (a) there are fifty to five hundred times as many power plants and other major units per million men and (b) entirely new types of equipments are making their appearance, all fairly bristling with instruments. Exact totals of particular types of instruments are military secrets but it is no secret that the number of "ordinary" pointer-and-scale indicating instruments serving our Armed Forces runs into many millions—in other words there are several such indicating instruments for every soldier, sailor, marine, merchantman and Coast Guardsman. These indicating instruments vary widely in their functions and internal mechanisms but every one has a pointer fixed to a shaft (or "spindle" or "shank") supported at both ends in natural sapphires or in ball bearings or in glass bearings or in synthetic gems or—rarely—in holes drilled in metal plates.

II. IMPLICATIONS OF THE REQUIREMENTS

Never before has there been such a combination of three requirements, the attainment of any of which would—at first thought—make impracticable and perhaps impossible the attainment of either of the others. This mutual exclusiveness seems to be particularly true of the first two: "everybody knows" that a sensitive direct-deflection indicating instrument cannot stand vibration and shocks; "everybody knows" that an indicating instrument built to stand abuse cannot be sensitive. And—"everybody knows" that the reason you can't have both is that a frictionless bearing is extremely delicate and the friction of a shock-proof bearing is so high as to be plain sticking. This is not a defeatist attitude; it does not proclaim that the problem cannot be solved under any circumstances; it simply states that none of the various well-known special solutions of specific sensitivity-versus-ruggedness problems is universally applicable—and this is an unassailable position. One solution, for example, is to substitute for one direct-deflection instrument a system consisting of a measuring element without moving parts, an amplifier without moving parts and a servo-positioned indicator so rugged that it could be dropped on a concrete floor without functional impairment. Another solution is to do away with all mecha-



Square wave applied to two amplifiers. Output of one on horizontal plates, output or other vertical plates for rapid comparison test. One amplifier defective shows up immediately whereas without square wave a long point by point frequency response would be required to discover deviation from standard.

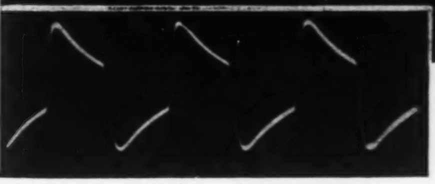
A new approach to the problem of measuring audio frequency equipment

One of the most recent approaches to the problem of measuring the response of amplifiers and networks is to apply a square wave voltage and observe shape of the wave which is transmitted. The frequencies contained in a uniform square wave are given by the relation:

$$f(t) = \frac{4}{\pi} (\sin wt + 1/3 \sin 3\ wt + 1/5 \sin 5\ wt + \ldots)$$

In practice a wave which appears to be perfectly square will contain thirty harmonics or more and when the amplitude or phase relation of the harmonics is disturbed the square wave will be distorted. Thus the application of a square wave to circuit shows up any irregularities in the amplitude or phase transmission of that circuit not only at the square wave frequency but also at frequencies far removed from the test point.

The square wave test is particularly important in feedback circuits where the circuit performance outside the normal transmission band is generally of interest. The application of a square wave test to a feedback amplifier will show in a single observation whether the amplifier is close to oscillation point.



Square wave distortion from poor response at both low and high frequency. (Oscillogram taken on a typical public address amplifier.)

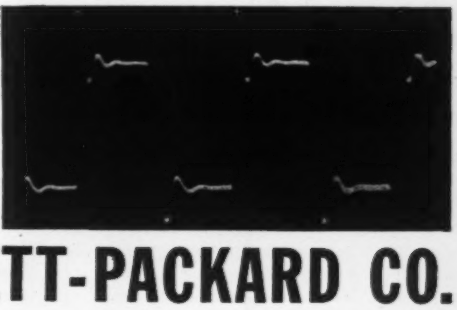
SPEED UP PRODUCTION AND DEVELOPMENT WORK . . . .

This Square Wave Generator will help you in Production and development work on A. F. amplifiers. As a general purpose instrument for laboratory work and as a time saver in production testing a square wave generator is an important instrument.

The -*hp*- model 210 Square Wave Generator provides an excellent square wave and is more useful than other instruments of this type because the frequency can be accurately set for quantitative measurements of decrement factor, time and other quantities to transient analysis. It will save valuable time in production testing because one or two observations will check the frequency response of apparatus where heretofore a large number of observations were necessary. This new instrument is an important tool for development work because it will show up phase shift and transient effects, both of which are rather difficult to study by other methods. In one observation a square wave applied to amplifier will check a wide frequency range, a range of 100 to 1 or even more. This is extremely important because once the proper criterion has been established a production test can be set up with one or at the most two observations with a square wave.

No priority needed to avail yourself of our engineering help but -*hp*- instruments are going all-out for war and quick deliveries can be made only to people engaged in the war effort. However, we are making prompt deliveries to war plants and our capacity for fast production is ample. Write today for information.

Square wave test on feedback amplifier showing amplification peak at 9 times square wave frequency. (A normal frequency response measurement shows flat response from 20 cps to 20 ks.)



HEWLETT-PACKARD CO.

BOX1135 D, STATION A · PALO ALTO, CALIF.

nisms and replace the pointer-deflection indicator by a cathode-ray tube indicator (various types withstand severe panel-board vibrations better than any sensitive mechanical indicator). Both of these solutions require auxiliary power; their practical embodiments weigh too much for most Army and Navy applications; they require the addition of a new class of specially-trained service men at maintenance bases; they can only be used with electrical or electronic primary elements and cannot conveniently be used for indicating many important factors such as rate-of-climb because (apart from several obvious reasons) the multiplicity of conversion stages creates an irreducible total error greater than the permissible variance. Another solution of the sensitivity-vs-ruggedness problem consists in designing an indicator wherein the actuating force and the spring torque which balances it are relatively enormous in comparison to the "stiction" of even a large, coarse bearing—even when this bearing is dirty and gritty. This idea, unfortunately, can only be used where energy-levels are sufficiently high: in mechanical applications the low differential of a Pitot tube, for example, would compel designing a diaphragm of absurdly large diameter; in electrical applications the most ingenious tricks with coil-turns, cobalt permanent magnets, etc., cannot step up microwatts to milliwatts and such expedients as, for example, the use of 1" diameter thermocouples to give lots of amperage, introduce thermal lags and other characteristics inacceptable to the Armed Forces. As a rule, the "brute force" solution of the low-energy-level case of the sensitivity-vs-ruggedness problem leads inevitably to designs suitable for huge industrial boiler-rooms, perhaps, but certainly not suitable for air, land and sea warcraft or portable equipments. In general, then, our Armed Forces' demand for (1) accurate indications and (2) accurate indications in spite of vibrations, shocks, humidity, grit, etc., could not be met by any single idea. It is not one problem but a number of individual problems. A few have not yet been solved; many have been solved partly and a few have been solved completely. It must be added that some of these problems had been solved before the war by aircraft and automotive instrument designers, by manufacturers of pocket exposure meters, etc., etc., and (indirectly but efficaciously) by the new science of vibration-minimizing installation.

But many of these new or old solutions of sensitivity-vs-ruggedness problems—even the presumably complete solutions—were not "complete" when consideration was given to the Armed Forces' third requirement, measurement of *all* important factors. This meant a tremendous increase in types and in quantities of instruments. It meant (a) huge production in the shortest possible time, (b) rejection of complicated designs entailing an unbalanced demand on manufacturing facilities and skilled workers, (c) rejection of constructions entailing greater tonnages or poundages of critical and strategic materials than would be available; (d) rejection of intricate designs and constructions which would require the Army and Navy to train millions of repair men and to set up unnecessarily huge maintenance shops all over the world. It is true that thanks to improved designs and constructions, the average service life of instruments under severe conditions has been lengthened by a hundred percent or more, but even if the "service men per 1000 instruments" figures of the commercial airlines, bus fleets, truck fleets, telephone companies, radio systems, etc., were divided by two for corresponding instruments, they would have to be multiplied by large factors for complicated high-sensitivity instruments. Furthermore, even if the experience figures of airlines, bus fleets, etc., were taken as a basis, simple arithmetic showed that servicing many millions of "sensitive" indicating instruments subjected to rough use would require setting up more extensive facilities and training larger numbers of maintenance men than ever before in the history of warfare. Since repair shops are not prime weapons and since repair men do not kill enemies, the total "service *hours* per 1000 instruments" had to be minimized to the utmost.

Now then, by far the greatest cause of stoppages or malfunctions of sensitive indicating instruments in war is damage to pivots and bearings. But, as we have seen, many "solutions" of this problem cannot be adopted when the real problem is the rapid production and effective military use of millions of instruments. It became obvious that bearings and pivots constituted the bottleneck of the instrument situation—one of the bad bottlenecks of the entire war production program. Shortly after Pearl Harbor a high Army Air Force technical officer* is said to have declared that the inventor of a bearing combining the low friction of the pointed-pivot-in-sapphire-cup and the ruggedness of the "alarm clock type" polished-shaft-in-brass-plate would deserve the Distinguished Service Medal, because this would obviate the need of training tens of thousands of instrument maintenance men in the next twelve months—not to mention halving the number of instrument factories to be built and saving hundreds of millions of man-hours on the home front. This impatient remark implies that an instrument with perfect bearings would not have to be replaced until it was "killed in action" and would require little servicing at infrequent intervals during its life—somewhat like the wonderful one-horse shay. The writer doubts that it was uttered exactly as reported above. The fact remains, however, that wherever large numbers of precision indicating instruments are subjected to rough service, bearing and pivot failures have accounted for more service department man-hours than any other single cause —more than all other causes, according to the records of some departments. This is not surprising because, whatever the type of instrument, it had to be disassembled more thoroughly in order to get at this trouble than was required for most other stoppages and malfunctions—and dismantling was followed by the largest number of time-consuming sequences of close inspections, hand-tool and machine-tool operations, reassembling, readjustments, etc. All this had become well-known by reason of decades of experience not only in various civilian-industry instrument departments but in our Armed Forces—particularly in the Army Signal Corps, which for years had had more high-grade indicating instruments per thousand men than any other large instrument-using organization in the world.

III. QUESTION POSED BY WAR

Why are low-friction pivots and bearings so fragile? An adequate answer, analyzing all factors, would take the form of an exhaustive "technical paper" too long and too dry for inclusion here. Besides, the real question is: Why are *conventional* low-friction pivots and bearings so fragile? The answer is: Because they consist of sharp-angle hard steel conical pivots in vee-cavity natural-sapphire jewel bearings. The pivot points are not quite needle-sharp but are spheroid surfaces with a radius of about one thousandth of an inch in the majority of cases. The bottoms of the vee cavities, likewise, are always rounded. As a rule, the radius of curvature of the bottom of the cup is about three times that of the rounded point of the mating pivot. If hardened steel and natural sapphire possessed no elasticity at all, the contact area of a 0.002" sphere in a 0.006" hemispherical depression would be little more than a geometrical "point" and for highly-polished (but not geometrically perfect) actual surfaces it would be about a ten-billionth of a square inch. Therefore, a featherweight load would create local stresses several times greater than the compressive yield points of steel and of sapphire, resulting in local cracks—microscopic or sub-microscopic cracks, to be sure, but irreparable cracks which, multiplying and spreading with every change of pointer position, would soon amount to disintegrated surfaces and an accumulation of steel dust and sapphire dust. Since both hardened steel and natural sapphire possess elasticity, even a featherweight load, by reason of elastic deformation, produces an increase in contact area. Small as it is, this elastic deformation is what makes the actual contact area suit the varying load and thereby prevent microscopic local overstressing so long as the instrument is handled with care.

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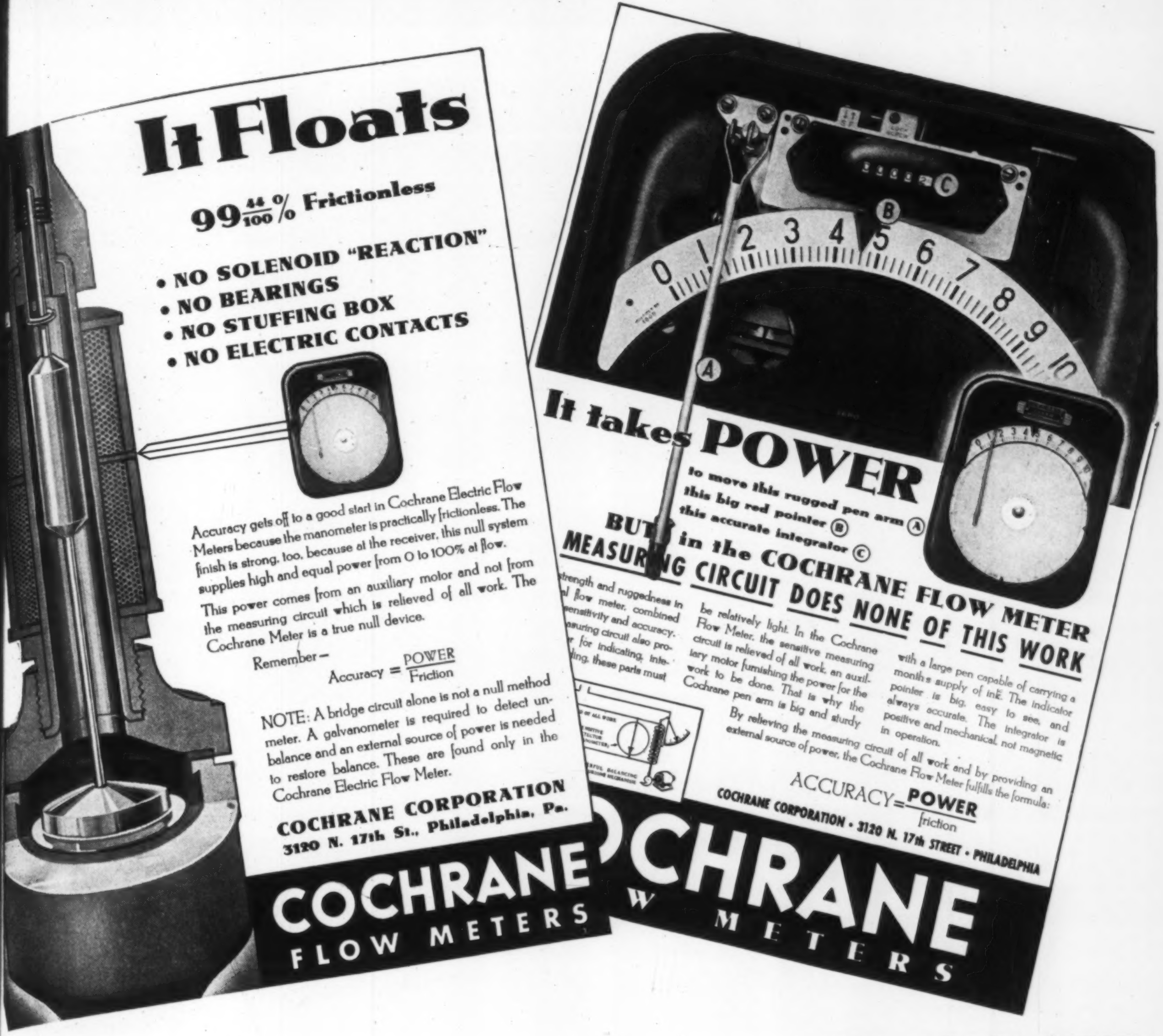
*Or a high Naval Aviation officer—I've heard it attributed both to General X and to Admiral Y.



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$99\frac{44}{100}\%$ Frictionless

- NO SOLENOID "REACTION"
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Accuracy gets off to a good start in Cochrane Electric Flow Meters because the manometer is practically frictionless. The finish is strong, too, because at the receiver, this null system supplies high and equal power from 0 to 100% at flow.

This power comes from an auxiliary motor and not from the measuring circuit which is relieved of all work. The Cochrane Meter is a true null device.

Remember—

$$\text{Accuracy} = \frac{\text{POWER}}{\text{Friction}}$$

NOTE: A bridge circuit alone is not a null method meter. A galvanometer is required to detect unbalance and an external source of power is needed to restore balance. These are found only in the Cochrane Electric Flow Meter.

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be relatively light. In the Cochrane Flow Meter, the sensitive measuring circuit is relieved of all work, an auxiliary motor furnishing the power for the work to be done. That is why the Cochrane pen arm is big and sturdy

with a large pen capable of carrying a month's supply of ink. The indicator pointer is big, easy to see, and always accurate. The integrator is positive and mechanical, not magnetic in operation.

By relieving the measuring circuit of all work and by providing an external source of power, the Cochrane Flow Meter fulfills the formula:

$$\text{ACCURACY} = \frac{\text{POWER}}{\text{friction}}$$

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You've got to have BOTH low friction and high power in a FLOW METER ... and you get both in

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Why are these two contact surfaces, at the ends of an instrument shaft, made so small? In other words, why so tiny a point and so tiny a rounded fill at the bottom of the vee cup? Simply to minimize frictional torque. This answer seems to contradict Coulomb's second and third laws which state that friction is proportional to load and independent of contact area, but experiments have demonstrated the superiority of small-area designs over large-area designs (other things equal) in this particular field of enhancing instrument sensitivity. If any readers remain skeptical, let them consider a horizontal instrument shaft supported at both ends by ordinary cylindrical bearings; next let them imagine another instrument shaft having at each end a long-spoked spider (shaped, for example, like a buggy wheel minus the rim) with total area of spoke ends equal to total bearing area of the first shaft; the materials are identical and the loads equal, but no reader will claim that the long-radius bearings will show smaller friction and most will know from experience with machines and gadgets that the long-radius bearings will show greater friction in spite of all other things being equal . . . including the coefficients given in reference books.

Why not provide for excessive momentary loads by using, instead of steel, a material with greater ability to deform elastically—a more "rubber-like" material? The answer is that hard steel is much more *elastic* than rubber. Too *resilient* a material would not do because the entire pivot cone would bend too much, causing rubbing of other instrument parts. It's always a compromise among various physical properties of available materials. More about this later.

Why not sacrifice some sensitivity to gain longer service life, by specifying larger contact areas—larger and stronger pivots and bearings? Manufacturers have for many years been doing just this—some of them rather empirically and even arbitrarily but others systematically. For example, a mirror-scale laboratory bench model of a good make will have extremely small-radius pivots and jewels; the corresponding portable "test grade" model embodying a moving element of exactly the same weight will have "medium" pivots; and that same moving element when embodied in a portable "service" model will be supported by "large" pivots. The guaranteed accuracies, of course, will generally be something like 0.1%, 0.75% and 2.5%. But the industrial or commercial "service" model will not be rugged enough for *military* service. Merely increasing the sizes of hard steel pivot point spheroids and of sapphire cup bottom roundings does not solve the general problem posed by the Armed Forces' three requirements.

Why is the conventional design considered the best one for combat instruments? Decades of experience in the *electrical* instrument industry have led to the acceptance of this design in the manufacture of indicators wherein the actuating torque and the restraining-spring torque are both extremely feeble. But the trend in *that* industry during the last four decades has been toward reducing power consumptions or "burdens" as well as toward improving sensitivities. In other words, the trend has been toward minimizing pivot friction in order to make possible (a) successive *reductions in the actuating torque* of each stock model as well as (b) the production of lower-range models undreamt-of thirty years ago. One of the dramatic milestones of this trend was Weston's announcement, about eight years ago, of a portable commercial instrument capable of indicating a fraction of a millionth of a volt. Such achievements by several electrical-instrument manufacturers naturally influenced almost everybody concerned when the National Defense program was started in 1940. It is generally believed that the conventional shapes and sizes of pivots and of cup bearings represent the most practical method, in the present state of the art, of minimizing the friction of the lightest-weight moving elements being manufactured, when the available actuating power is of the order of "a small fraction of a fly-power." There is no basis for believing that this conventional design is the best for medium-weight or relatively heavy moving elements. There is every reason to believe that this conventional design is far from the best of available and service-tested designs for application to relatively heavy moving elements deflected by relatively large forces. Indeed, it is so obviously inferior to other designs already developed that one of these other designs, namely the miniature ball-bearing, is winning enthusiastic advocates.

Why are not miniature ball bearings generally believed preferable even for feeble-torque applications? Because they are not being made small enough at the present time: the industry is new and, although its products are amazingly minute and uniform, the smallest ones in regular production are too "large." This requires explanation: Theoretically, any rolling-contact design (ball, roller, etc.) would be preferable to any sliding-contact design, regardless of size, but tests have shown that—exactly as in the case of the contact areas of conventional pivots—there is an optimum size for every type of application. To put it crudely: a buggy wheel would be improved by equipping it with bicycle-wheel size ball bearings but not with railway Timkens. The smallest miniature bearings of exactly-controlled manufacture and strictly-guaranteed performance are still "a couple of sizes" too large for the sensitive low-torque instrument applications today. To-morrow, advances in technique will have extended the size range.

Granting that the conventional design is the most practical for "fly-power" light-weight-element applications, why are hard steel and natural sapphires generally used in preference to other materials? There are two one-word answers: Experience and habit. By experience we mean that the evolution of the conventional pivots and jewels began with steel and sapphires and therefore has been, in effect, a half-century of research and development on the optimal shapes and sizes for this particular combination of materials.[*] By habit we mean that the apparent supremacy of steel and natural sapphire, due to lack of extensive work with other combinations until recently, has in effect worn a mental rut. There is no basis for believing that the combination of steel and natural sapphire is the best or even one of the five best among the numerous combinations known today. There already are reasons for believing that other combinations are superior in several important respects, even if the conventional shapes and sizes gradually developed for steel and sapphire are not modified. Corrosion-resistance is a property that must be possessed by functional parts of instruments for our Armed Forces—and it is the very property in which steel is notoriously deficient. The various so-called "stainless steels" developed up to the present time are unsuitable as raw materials for pivots by reason of their coarse grain structure and other unfavorable physical characteristics. To-morrow, perhaps, when you see stainless-steel razor blades in your drug store, you will know that metallurgists have developed a corrosion-proof ferrous alloy suitable for instrument pivots. It is perfectly true that instruments for the Armed Forces must have cases with "close-fitting joints" that "limit the entrance of dust and moisture" (wording of War Standard approved January 1943) but this is a far cry from having hermetically sealed cases. In humid climates where the day and night temperature difference exceeds 50°F., instruments "breathe" considerably and a case originally filled with pure bone-dry dust-free air will, if it is not air-tight, contain atmospheric moisture (and other atmospheric contaminants) after a few days and nights in such a climate.

IV. PRESENT SITUATION—REVOLUTION WELL UNDER WAY BUT NO "END POINT" IN SIGHT

One purpose of this article having been achieved by the heterodoxical preceding sections, this section will systematically touch upon specific phases of the present situation—some mentioned before, others not. Some of these subjects have been and others deserve to be treated in detail

(Continued on Page 282)

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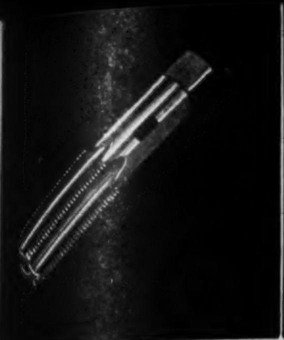
[*] If other materials had been available in 1887, there would have been several simultaneous evolutions resulting today in several sets of optimal shapes and sizes—one set being the familiar one, another set for the combination of steel and some particular synthetic gem, another set for some particular non-ferrous alloy in combination with natural sapphire, etc., etc. The combination of steel and natural sapphire might then be one of the minor ones today.



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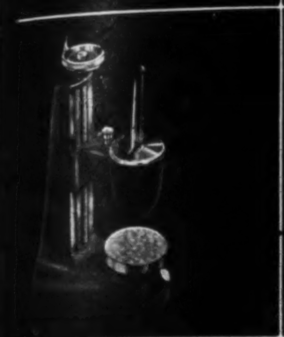

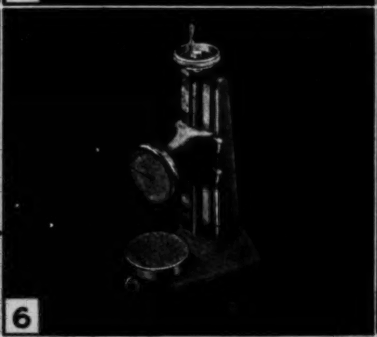

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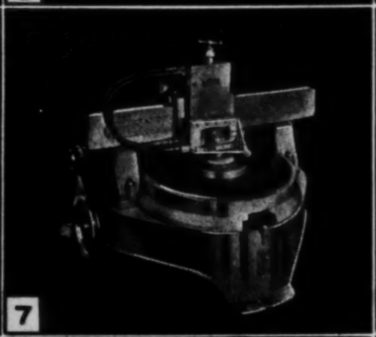

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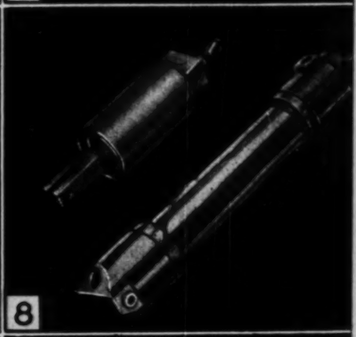

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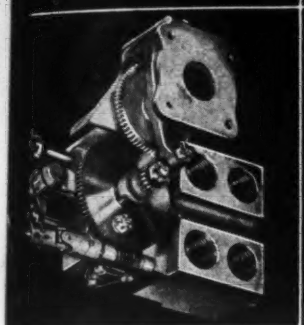

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11

12

These are VARD's contributions to American manufacturing supremacy

Here are twelve products, developed in our engineering department and converted into commercial manufactured items in our technical shops.

These twelve fall into three classifications: precision checking tools of high fidelity, operating instruments for aircraft and ordnance manufacture, and optical goods and a process of treating optical glass.

In the picture above, No. 1, shows a VARD precision tap. We build these to order of special steels, special and left hand threads—in fact, the kind hard to get anywhere else. No. 2, is an internal thread ring gage. We build these in a wide variety of sizes with similar, cylindrical, ring gages. No. 3, is a plug gage, with "Go" and "No Go" threads. These, as well as cylinder plug gages, are built in all sizes. No. 4, is one of our plain taper, ring gages for checking pipe threads.

Far more sensitive and accurate than the first four, are the VARD external comparators, No's. 5 and 6, above. These beautifully made checking instruments, quickly indicate variations in size of work one ten-thousandth of an inch. Both are bench models, easy to move and easy to read.

No. 7, is a circular dividing machine. It accurately divides circular discs into predetermined segments. It is used in the manufacture of dials, protractors and instruments. We build both circular and linear dividing machines.

Actual operating parts of planes, such as the hydraulic cylinders, No. 8, and wing flap indicator, No. 9, are precision built to plane manufacturers' design. We have turned out a great quantity of such equipment and are now increasing our plant to handle more.

Optical lenses, mirrors, and filters, as shown in No's. 10 and 11, are important among our products. In the processing of some of these units, we use a newly developed scientific method of vacuum-evaporation, No. 12, to deposit durable coatings on the glass. These coatings, either form a brilliant reflecting surface, in mirrors, or materially reduce surface reflection, in lenses or prisms. This process of Opticote is a new scientific discovery.

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Instrument Men Represented in WPB

Abstract of a talk by HARVEY P. ROCKWELL, Jr., before the American Society for Measurement and Control, Pittsburgh, Pa., March 8, 1943

INSTRUMENT men who are working with measurement and control devices sometimes lose sight of the real miracles performed by instruments. I wish it were possible to tell the entire story of war-time instruments to show how they are actually landing planes, directing guns, simplifying navigation, and finding the enemies so that our soldiers, sailors and marines can exterminate them.

Then, of course, there is the more common variety of instruments such as the little voltmeter and the pressure gage doing a routine but important job to insure high standards of quality and efficiency in operation.

But where does the War Production Board fit into this instrument picture? With facilities, materials and labor very short, the War Production Board endeavors to help all manufacturers get more production from less of these three fundamental ingredients. The important thing to be remembered is that the War Production Board is not just another source of questionnaires but rather a group of men like yourselves, direct from industry, thoroughly acquainted with your problems and most eager to assist in their solutions.

It is true that the organization is not perfect. Probably no one has gathered together over 20,000 people in a period of slightly more than one year and found each and every one without flaws. But overall, the War Production Board has done certain jobs which no individual could have done single-handed. Take, for example, the case of the automotive industry. We can appreciate that this industry is seriously needed for war production, but until someone could direct the entire industry from civilian pursuits into the war work, the best interest of the country at large could not be served.

Today, Boeing planes are being made in the Lockheed and Douglas plants. Bringing this down to terms with which we are more familiar, it is the same thing as having Ford and Chevrolet build Plymouth cars and put Plymouth names on them. However, when Americans realize there is a need, and know the reason clearly, they are willing to make any sacrifice to achieve the end.

From this it follows that when the Armed Services show their needs to a group of men from industry acting to speed war production, the result will be an increased tempo of armanent operation.

One of the large users of electrical measuring instruments is the radio and radar industry. They are, in fact, using more than half of these instruments as well as a number of other critical components such as capacitors, vacuum tubes, resistors, and the like. Many of these items are gathered in the Radio and Radar Division of the War Production Board to be handled by specialists from industry who have come to Washington, with the prime object of seeing that sufficient quantities of each item are made available to the Armed Forces when needed.

It might be interesting to have a little idea of the organization of a typical Component Unit, From the organization chart herewith, it can be seen that such a Unit is built around a Military Advisory Committee and an Industry Advisory Committee composed of representatives familiar with the problems and able to guide the activities of the Unit.

In addition, there are Consultants from the Armed Services and the Industry who work directly with the Unit to see that the problems, both military and industrial, are considered.

The three operating groups of the Unit are headed by

(1) a requirements engineer
(2) an operations engineer
(3) a production engineer

By means of these groups it is possible to give industry an idea of the requirements that they can expect for a particular period of time. The operations engineer is charged with the responsibility of knowing the plant load, capacity and shipments of the products in question. The production engineer supplies the facilities, materials and schedules of production.

Industry, of course, has many problems such as relating its facilities to military requirements, obtaining critical materials, and operating under many restrictions laid down by the war economy. Industry recognizes that it has a related Unit in Washington to which it can look for assistance from men whose association with Industry enables them to know the problems first hand. In addition, the field staff of the War Production Board is frequently able to render assistance quickly and effectively on many local problems.

WAR PRODUCTION BOARD

RADIO AND RADAR DIVISION, ELECTRICAL INSTRUMENT UNIT
Location: Social Security Building, Third Street and Independence Avenue
The telephone number of the WPB is Republic 7500
Organization, Personnel, Function, Room and Telephone Numbers

Name of Individual	Position	Processes	Room	Phone Ext.
Harvey P. Rockwell, Jr.	Chief of Unit	—	4035	75675

Military Requirements Group

This group determines and correlates the needs of the Armed Forces.

Name of Individual	Position	Processes	Room	Phone Ext.
Frank G. Vaughn	Executive Assistant	—	—	—
P. W. Mack	Requirements Specialist	—	4043	76393
Anna L. Schlosselman	Assistant Analyst	—	4035	75675

Operations Group

This group plans and guides the industrial activities of the industry.

Name of Individual	Position	Processes	Room	Phone Ext.
R. R. Simpson	Executive Assistant	—	—	—
F. A. Adkins	Associate Operations Engineer	L 203	4061	74187
Walter Delany	Asst. Approval Analyst	PD674	4061	74187
Charles Brett	Asst. Operations Analyst	PD675-6	4059	74487
Barbara Bradfield	Senior Statistical Clerk	WPB 1686	4059	74187

Facilities and Materials

This group assists in obtaining facilities and materials.

Name of Individual	Position	Processes	Room	Phone Ext.
Harry P. Sparkes	Executive Assistant	—	—	—
C. V. Burmaster	Associate Industrial Specialist	—	4059	74487
George G. Hoye	Asst. Industrial Analyst	CMP4B	4059	74487

Rescheduling

This group offers emergency assistance.

Name of Individual	Position	Processes	Room	Phone Ext.
H. L. Olesen	Executive Assistant	—	—	—
H. D. Johnson	Associate Industrial Analyst	—	4057	2832
L. M. Randall, Jr.	Associate Industrial Analyst	—	4057	2832

Forms Listed Above Under Processes

Form No.	Title
CMP-4B	Application for Allotment of Controlled Materials for Class B Products
PD674	Application for Authorization to Reserve Delivery of Combat Measuring Instruments
PD675	Small Panel Electrical Combat Measuring Instruments, Supplier's Monthly Delivery Schedule
PD676	Combat Measuring Instruments; Supplier's Monthly Operations Report
SR1	Application for Special Rating
WPB-1686	Combat Measuring Instruments; Supplier's Product Classification

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l. 11, No. 5 M. F. Behar, Editor MAY 1943

Tester for Ratio Type Dual and Single Thermometer

By PAUL S. WHITE

Inspector (name of plant deleted), La Crosse, Wis.

HE dual and single ratio type electrical universal thermometer offers perhaps the greatest opportunity for development of portable test equipment for conience in assuring the contractor as well as the inspector t the product is in perfect operating condition before al packing and shipment is made.

Due to the many difficulties encountered in the manufacre of this instrument, to its comparative newness and to s progress from more or less the embryonic stage for the neral instrument manufacturer, it has become necessary construct new test equipment capable of handling it on production basis.

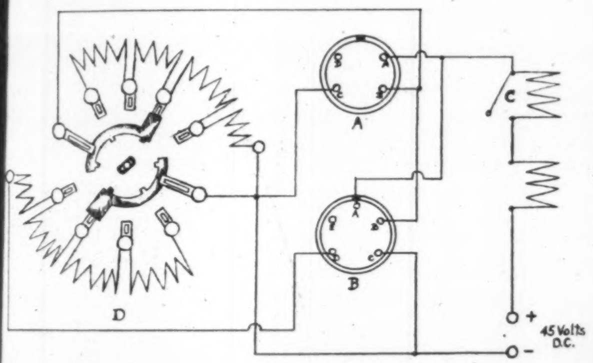
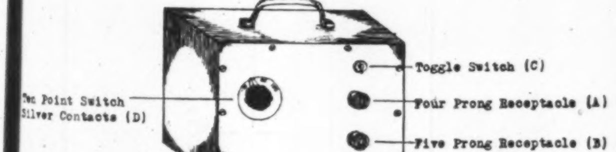


Fig. 1

The portable test unit illustrated herewith has been deloped and has proved highly successful because of its mple construction and ease of operation. It is so designed hat the thermometer, single or dual, may be plugged into he receptacles *A* or *B* respectively and tested for four diferent temperature: –70°, 0°, 80° and 150° Centigrade, hich allows full dial coverage. With the wiring followed s illustrated, it is possible to check both sides of a dual hermometer, thereby allowing the pointers to pass each ther in checking for interference (which is possible due to he small clearance between them). At the same time, calibration is rechecked and the operation of the instrument in all positions may be determined by inverting the test unit. This unit is provided with a handle for convenience in carrying and an internal voltage supply which consists of a 45-volt battery.


Toggle Switch (C)
Ten Point Switch Silver Contacts (D)
Four Prong Receptacle (A)
Five Prong Receptacle (B)

ig. 2

With the switch *C* a resistor is mechanically cut into the circuit, which provides the means of checking the dual or single at will.

The schematic wiring diagram is self-explanatory. It has been used with a high degree of success.

Trouble-shooting the Electrical Tachometer System

By HARRY E. GEDDES

Senior Mechanic, Electrical Instruments, American Airlines.
Instructor, New York School of Aircraft Instruments.

WITH the coming of two- and four-motored airplanes, a better and more efficient way of communicating the rotational speed of the engine to the pilots' compartment had to be found. The old way of using a flexible shaft driven by the engine to operate a centrifugal tachometer had reached its limits. The length of a flexible shaft is limited to about 25 feet for efficient operation. The installation of the flexible shaft had to be without sharp bends, otherwise this would cause a whipping action of the shaft resulting in an erratic or fluctuating movement of the indicator pointer. This is in direct contrast to the electrical tachometer system where there are no limitations as to the amount of sharpness of the bends in the connecting wires. For instance, consider the Weston Model 724 tachometer magneto and Model 545 indicator as illustrated in Figs. 1 and 2.

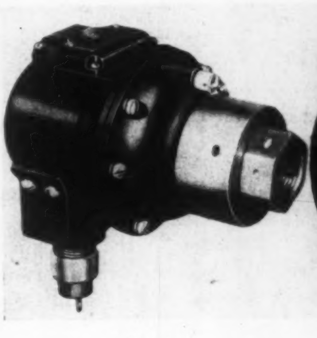


Fig. 1

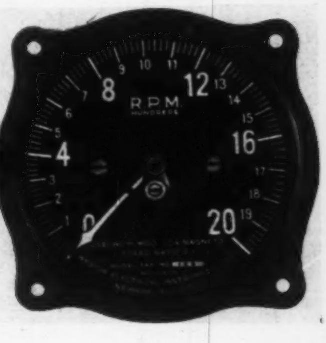


Fig. 2

The magneto is a two-pole d-c. generator which uses a ring type cobalt magnet as a field. This is also known as a permanent-magnet type d-c. generator. The voltage and current generated depend upon the speed of the armature in cutting the lines of force of the permanent magnetic field.

Trouble: No reading—Either permanent or intermittent

Possible cause	Remedy
Short circuit in leads	Repair
Break in lead	Repair
Poor connection at magneto plug or at indicator binding posts	Clean and tighten
Break in indicator or magneto	Replace and return to instrument shop

Trouble: Low reading—Either permanent or intermittent

Possible cause	Remedy
Poor connection at magneto plug or at indicator binding posts	Clean and tighten
Oil or water seepage at magneto plug and socket or in wire conduit	Clean and dry
Zero corrector screw off adjustment on indicator	Disconnect lead and reset pointer to zero
Coupling to magneto loose	Tighten
Coupling to magneto worn	Replace and return to instrument shop
Magneto brushes worn or indicator pivots dull	Replace and return magneto or indicator to instrument shop

Trouble: High readings—Either permanent or intermittent

Possible cause	Remedy
Zero corrector screw off of adjustment on indicator	Disconnect lead and reset pointer to zero
Indicator resistance off adjustment	Replace and return indicator to instrument shop

The open-circuit voltage at 1000 r.p.m. is 6 volts. By open-circuit voltage, we mean that with the armature of the magneto turning at a speed of 1000 r.p.m. and with no indicator connected to its terminals, the resistance of the magneto is 200 ohms and an internal voltage drop occurs when used with a Model 545 tachometer indicator. Due to the load of the indicator being placed on the magneto, the voltage at a given speed will be less than the open-circuit voltage. This is governed by the current drawn by the indicator multiplied by the resistance of the magneto. The sensitivity of most Model 545 tachometer indicators is 7.5 milliamperes for full-scale deflection. Therefore, when the indicator shows full-scale speed, the drop in voltage in the magneto is 1.5 volts. The Model 545 indicator mechanism is designed to permit a 270° scale deflection of the pointer. The theory of operation is the same as the conventional d-c. movement except that the magnetic flux is distributed over this larger deflection angle by a suitable design of the core and pole pieces.

INSTALLATION

The complete system consists of a tachometer magneto and indicator for each engine with the necessary connections and wiring. The indicator should be installed in a properly shock-mounted panel. Little trouble will be experienced with this system during normal operation but it should be inspected periodically to make certain that all electrical connections are clean and tight and that the insulation on all connecting wires is not frayed or broken. The connecting plug on the magneto should be inspected thoroughly to see that no oil or water has seeped into it.

TROUBLE-SHOOTING

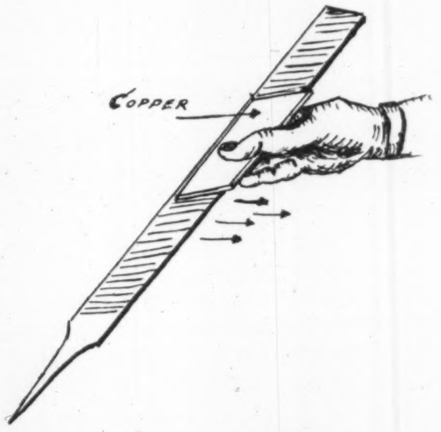
Wear or severe vibration are the usual causes of troubl I have listed some of the more common causes of this sy tem giving a poor or intermittent operation. Where I ha mentioned to replace the indicator or magneto and send d fective part to the instrument shop, this applies mainly an airline or organization which maintains its own repa department with mechanics who are specialists in their ow line of work. A private pilot who experiences trouble wi his tachometer system should go to an approved instrumen repair station or return the defective indicator or magnet to the factory for repairs.

Cleaning Small Bench Files

By GEORGE E. KERN

20th Airdrome Squadron, Army Air Base, Salina, Kansas

CHALKING a file is sometimes used to prevent chip from clogging the teeth. However this is rather mess and a piece of chalk is seldom at hand. Here is a kin



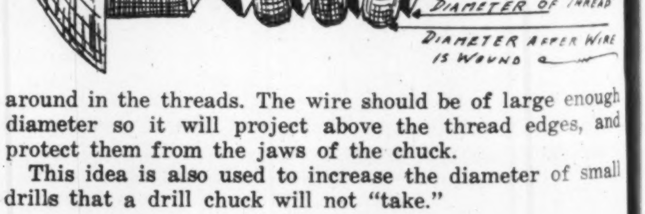
handed down by an old-time jeweler. A flat straight edge piece of copper (scrap will do) thick enough so it will not bend when pressure is applied, is drawn diagonally across the file, in line with the cutting of the file. The idea is that lines will be cut in the soft copper. Draw the copper across the file until all chips are removed. A clean file is the result of the effort.

Protecting Screw Threads from Damage When Holding in Lathe Chuck

By GEORGE E. KERN

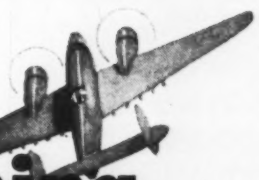
20th Airdrome Squadron, Army Air Base, Salina, Kansas

WHEN a special screw has been turned, threaded and cut off the rod, the head has to be finished. To hold the threaded part in the chuck, wind a length of wire


DIAMETER OF THREAD
DIAMETER AFTER WIRE IS WOUND

around in the threads. The wire should be of large enough diameter so it will project above the thread edges, and protect them from the jaws of the chuck.

This idea is also used to increase the diameter of small drills that a drill chuck will not "take."



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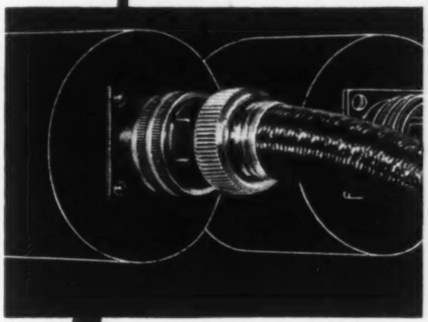

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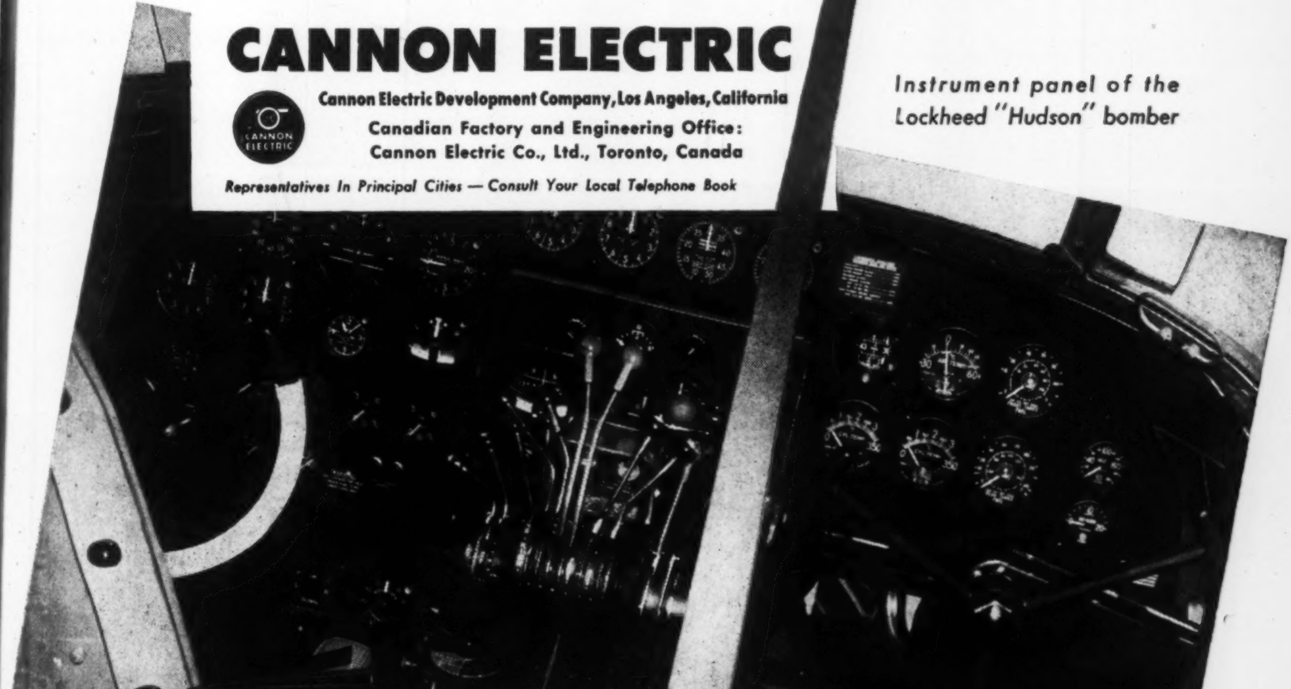

Instrument panel of the Lockheed "Hudson" bomber

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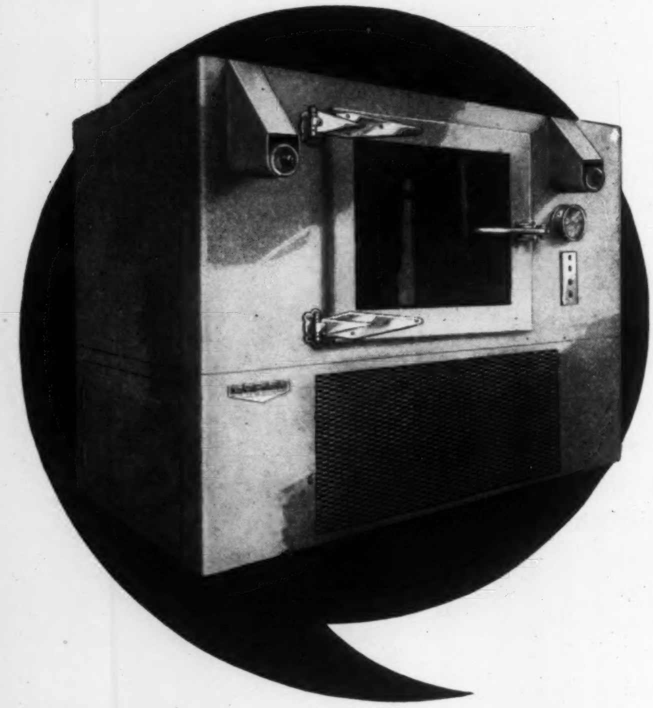

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The following articles (to the bottom of Page 278) have been contributed by the Aircraft Instrument Guild. For further information on any of the subjects discussed, write to the Guild at the above address.

How to Spot-weld Chronometric Tachometer Corrector Wheel

By L. H. HARVAT

Spartan School of Aeronautics, Tulsa, Okla.

AFTER much experimenting, a method has been found for keeping the corrector wheel of Jaeger chronometric tachometers from becoming loose and throwing the instrument out of calibration. The method involves the use of the jig illustrated herewith, in conjunction with an electric arc welder (jewelers' type preferred).

Fig. 1 shows the Y-shaped brass plates of which three are required (top, middle and bottom) with holes and dimensions. Fig. 2 shows the three Y-shaped brass plates in position with pens and nut on bottom plate, the butterfly bolt inserted from the top and the two brass plate spacers soldered to bottom and middle plates.

Fig. 3 shows the carbon electrode and holder. The carbon can be taken from a pen-flashlight battery and turned down to a point for contact. Holder for carbon may be made of brass rod.

The wheel is placed in the jig in this manner: First, slide into place the center Y-plate which fits between the wheels of the corrector wheel and around the tension spring. Insert

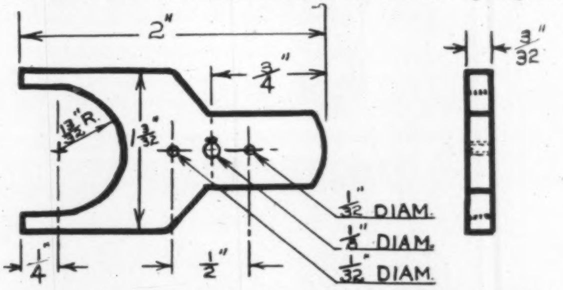

2"
3/4"
13/32" R.
1 3/32"
3/32"
1/32" DIAM.
1/8" DIAM.
1/32" DIAM.
1/4"
1/2"
NOTE— 3-REQUIRED

FIG. 1

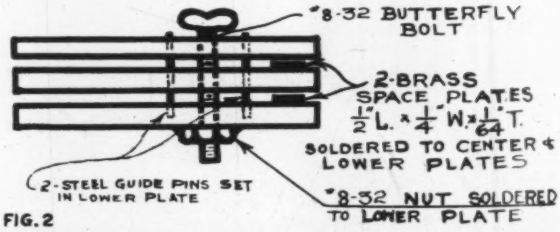

#8-32 BUTTERFLY BOLT
2-BRASS SPACE PLATES 1/2" L. × 1/4" W. × 1/64" T. SOLDERED TO CENTER & LOWER PLATES
2-STEEL GUIDE PINS SET IN LOWER PLATE
#8-32 NUT SOLDERED TO LOWER PLATE

FIG. 2

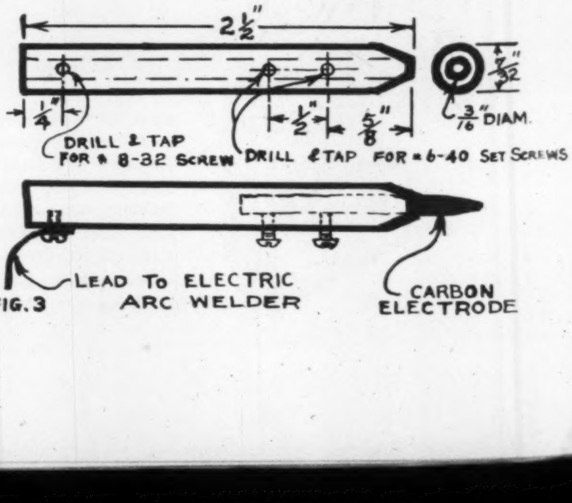
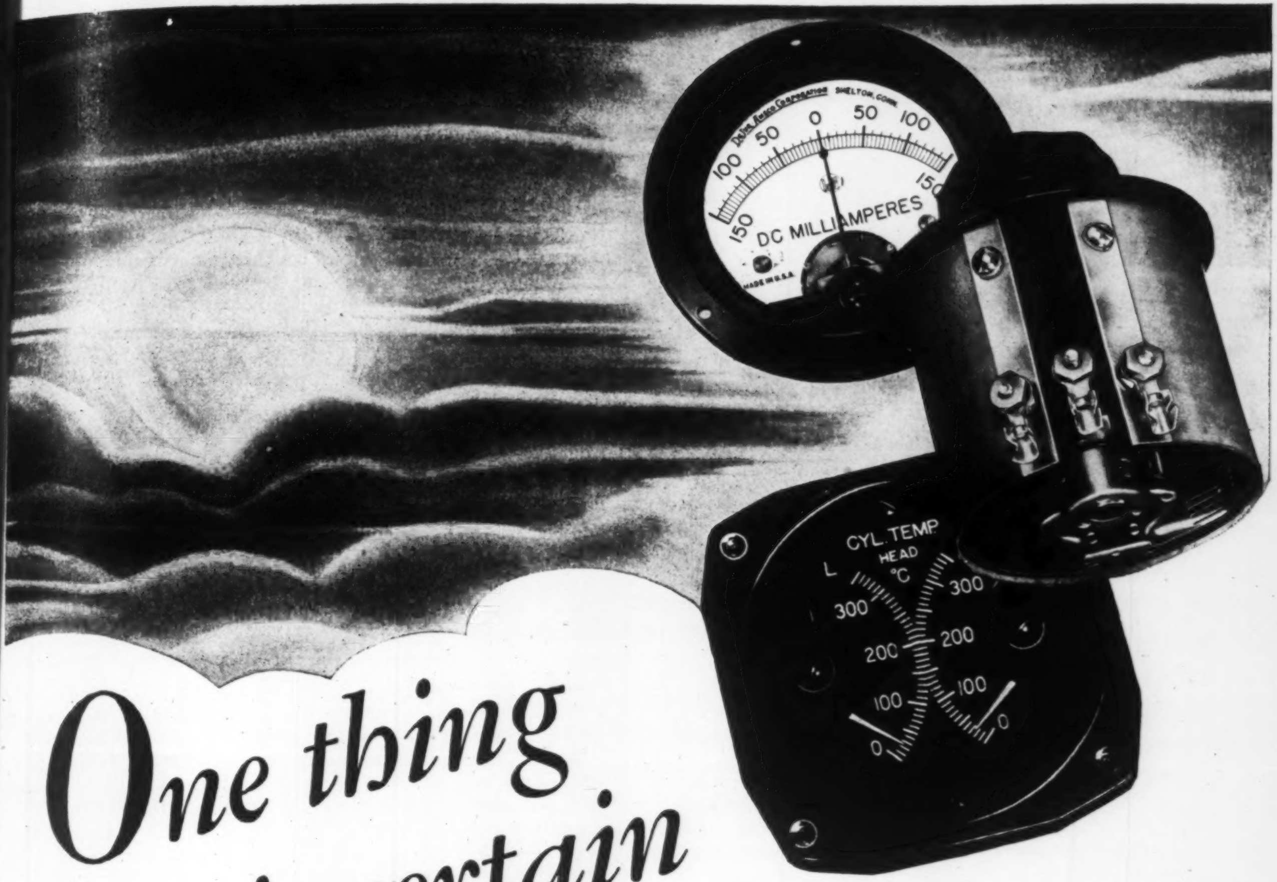

2 1/2"
7/32"
3/16" DIAM.
1/4"
1/2"
5/8"
DRILL & TAP FOR # 8-32 SCREW
DRILL & TAP FOR # 6-40 SET SCREWS
LEAD TO ELECTRIC ARC WELDER
CARBON ELECTRODE

FIG. 3



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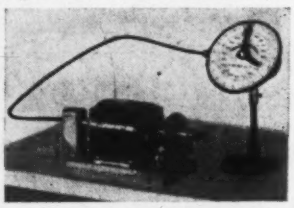

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the bottom plate with the nut and pens attached, which i pushed through from the bottom. The upper plate is the placed on from the top and the bolt is screwed down firml to create good electrical contact and hold in position whil welding. Be sure to line up the studs on corrector wheel t the exact 45° angle before tightening the bolt and assembly. This jig is mainly used to hold the wheel in position (45 angle of studs) and to keep it from warping because of th heat used in arc welding. This jig should be fastened firmly to one wire of the electric arc welder and the carbon electrode attached to the other contact. Spot weld the wheel i about three or four places on both sides. (A little preliminary practice is worthwhile as the proper amount of hea applied fast is important. A slow heat will cause warping.) Last, clean off with wire brush or emery paper.

The A.I.G. Q&A Column

Conducted by E. M. ALLSMAN

Recorder, Aircraft Instrument Guild

Q. Instructions with our new portable C-1 Test Set include a check for the manifold pressure gage in which the readings are compared with those on the Master Suction Gage. How may this be accomplished when the manifold pressure gage measures absolute pressures while the suction gage is a differential-pressure measuring instrument? (D. H., Miami, Fla.)

A. The manifold pressure gage is actuated by an aneroid which is sealed at a given pressure and, consequently, it will give an indication of any deviation from this condition. Therefore it is affected by changes in atmospheric pressure and, for any given instance, it should indicate the existing barometric pressure when the engine is not running. Whenever the engine is operating, the resultant reading is one of differential pressure based upon the existing pressure, or proportional to the difference of the pressure inside the case compared to that on the inside of the capsule. (This arrangement is necessary to compensate for changes in altitude and barometric pressure.)

Thus it is quite apparent that we may, in a comparative manner, test the manifold pressure gage against the limited scale of the suction gage in that the pressure within the case of the former is the same as that inside the diaphragm of the latter.

Preceding the test we must ascertain that the manifold pressure indication is within the required zero tolerance by comparing it with the existing atmospheric pressure as shown on the barometric scale of the sensitive altimeter, pointers set to zero. As suction is slowly applied, the reading should vary from the existing station pressure by the amount indicated on the suction gage. Similarly, it is possible to test the instrument on the pressure side. Please bear in mind, however, that this is intended only as a general check for the installation and is not to be considered adequate for a bench test.

Q. Why are cylinder temperature gages used with some liquid-cooled engines? (S. L., Kansas.)

A. This installation is used to indicate base temperature.

Trouble-shooting Chart for Chronometric Tachometers

By F. E. HONEYCUTT

Night Foreman, Spartan Instrument Overhaul Dept., Tulsa, Okla.

MANY questions have been asked regarding the chronometric tachometer. The following is a list of possible causes for errors in this unit. Of course it is common knowledge that if the instrument is properly assembled and all parts are perfect, we will have a perfect instru-

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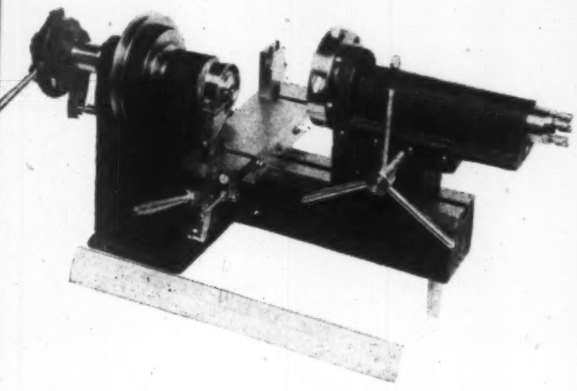
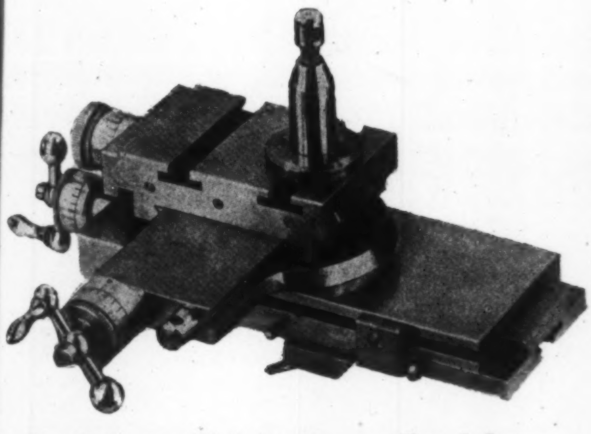


Two Sizes—3/16" and ½" Bar Capacity
9" Bed and 4" Swing
Both Sizes Have Lever Collet Closers

COMPOUND SLIDE REST



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COLLETS

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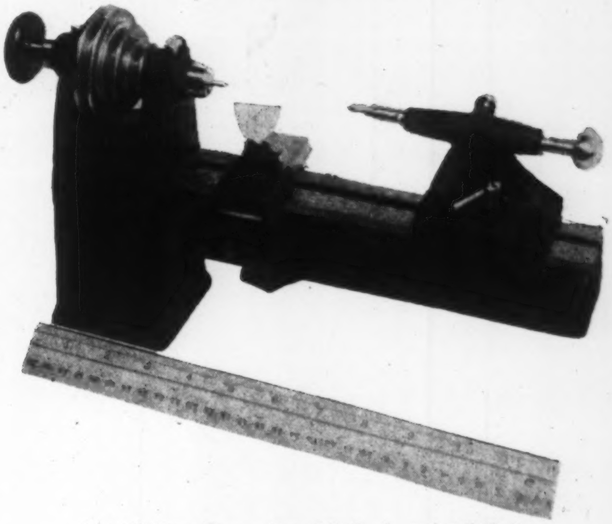
MOTORS—¼ H. P. and Smaller

INSTRUMENT REPAIR LATHES



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ment. But, due to the large number of moving parts a the speed some of these parts travel, worn conditions w be created that are not overly apparent; even then so may be missed until calibration brings out these erro after which the following outline may be used to good a vantage. [The symptoms are printed in **bold-face** type a the causes of errors listed below.]

I. Pointer does not move from neutral position.
A. Defaced gears:
  1. Drive shaft.
  2. Reverse gear mechanism
    a. jammed pinions.
  3. Commander:
    a. frozen.
    b. broken pin.
  4. Floating pinion:
    a. disengaged or thrown.
      (1) too much or too little tension on drag link arm.
      (2) worn pivots.
  5. Integrator.
B. Broken studs on integrator and corrector assembly.
C. Index finger misplaced or broken.
D. Inoperative cam:
  1. Mainspring broken or slipping on arbor.
  2. Hub washers broken.
  3. Anchor assembly:
    a. pins bent, worn or broken.
    b. throat and guard worn or broken.
  4. Balance assembly:
    a. roller pin broken, bent or out of alignment wit anchor assembly.
    b. hairspring collet loose on staff.

II. Pointer ascends at intervals and does not descend.
A. The bottom forkspring is not disengaging integrator gear.

III. Pointer ascends and descends at intervals;.
A. Disengaged forkspring.
  1. Corrector gear.
  2. Integrator gear.

IV. Pointer doesn't descend.
A. The middle forkspring is not disengaging corrector gear.

V. Pointer oscillates.
A. The corrector or integrator forkspring is blunt.
B. The corrector teeth are blunt or defaced.
C. The hub or corrector assembly is too large.

VI. Pointer spins.
A. The floating pinion is not disengaging the integrator.

VII. Pointer does not completely return to neutral position.
A. Too much tension on top forkspring.
B. Not enough tension on corrector spring.
C. Weak mainspring.

VIII. Pointer stops at a certain graduation.
A. One or two defaced teeth on the integrator.

IX. Pointer ascends and descends while instrument is face **down, but checks OK while face is up.**
A. Too much end shake in cam assembly.
B. The integrator forkspring is riding on shoulder below lower cam.

X. The reason for a curve.
A. The corrector gear slipped. (Decrease distance between studs and stake.)

XI. Three ways to speed up calibration.
A. Lengthening hairspring.
B. Decrease the distance of studs on corrector assembly.
C. Add weights.

XII. A simple test to check for unstaked or loose corrector **assembly before putting into case.**
A. Disengage the corrector forkspring. Turn the pointer around to ten thousand graduation and let snap back at least three times, then check for calibration. If a change appears, the corrector assembly needs to be re-staked or spot welded.

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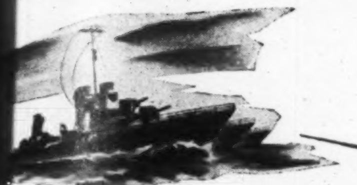
*For spot welding method, refer to article by L. H. Harvat in this issue of *Instruments.*



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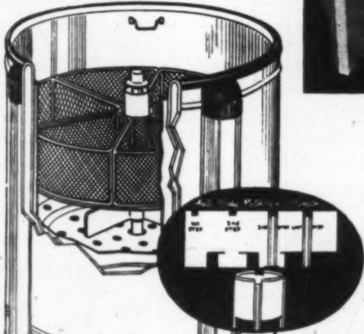

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Remote Control Method

Concluded from page 252

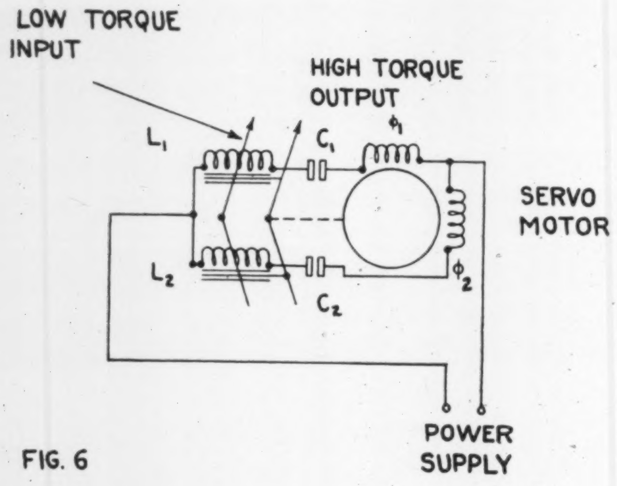

FIG. 6

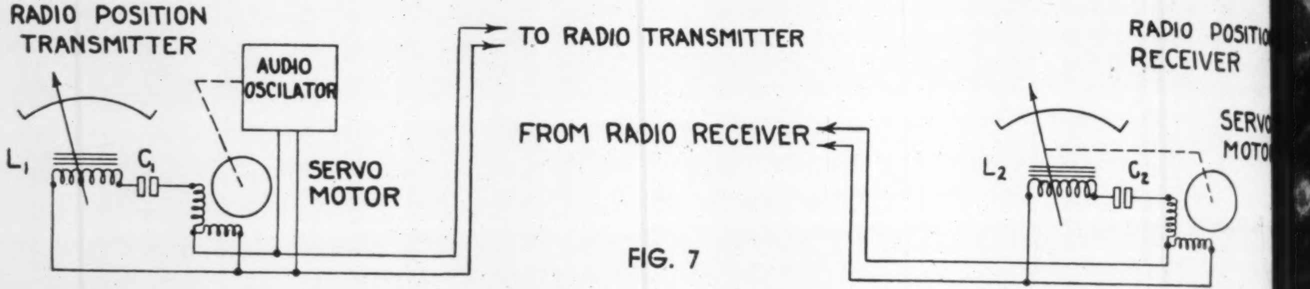

FIG. 7

with the transmitting and receiving inductances combined into one unit. The low-torque shaft varies the position of the inductance rotors, and the servomotor adjusts the inductance stators, maintaining a resonant condition at all times. This assures constant mechanical relationship between the stators and rotors of the inductances. This system may be made relatively compact and with electronic amplifiers may be made dynamic in action. It is suitable for continuous 360° operation.

RADIO CONTROL

All of the systems mentioned so far are suitable for wire operation. Fig. 7 illustrates a radio position-transmission system capable of definite proportionate position control over a radio carrier. The receiving part of the radio system consists of variable inductance L_2 and C_2, and a servomotor. Phase one of the servomotor is in series with the inductance and the capacitance, and phase two is made essentially resistive and connected directly across the alternating voltage supply, in this case the output of the radio receiver. Such a circuit is essentially a frequency meter supplied from the radio receiver. The position transmitter consists of a similar circuit with the servomotor operating an audio oscillator which is used to modulate the radio transmitter. The transmitter servomotor adjusts the audio oscillator frequency to the resonant frequency of L_1 and C_1. This frequency modulates the radio transmitter and therefore excites the position receiving circuit which is adjusted by the receiving servomotor until it is resonating with the applied frequency. If L_1 and L_2 are identical mechanically-variable inductances, and C_1 and C_2 are equal, the position of the control shaft of L_1 will be duplicated by the position of the control shaft inductance L_2. The servomotor in the transmitt is included to permit satisfactory field operatio If the audio oscillator drifts during warm-up, or any other time, the servomotor corrects the dri since it maintains the oscillator frequency equal the resonant frequency of the circuit L_1C_1.

Multi-channel radio control may be obtaine with the above radio circuit by assigning a fr quency band and modulating different sub-carrie frequencies with each separate control, filterin them at the receiving end. The carrier system i more satisfactory for a large number of channel and the individual frequency band system is appl cable for operation of two to four channels. An type of vehicle could be positively controlled by thi system because the control is continuous and no intermittent or based upon a step-by-step arrange ment.

CONCLUSION

It is hoped that this article illustrates the resonant control principle and some of its typical applications. Operating models which have been constructed have demonstrated many applications of the principle. Development is continuing and any suggestions for further applications and uses from the field would be gratefully received.

Photoelectric Measurement of Colo

INTEREST in the measurement and quantitative specification of color has grown rapidly in recent years because of the increased use of numerical designations of color in purchase specifications for paint, paper, ceramic, and other materials, and because of the increased attention given to the appearance of many finished articles sold on the market. The photoelectric tristimulus method of measuring color is simple and direct, and its possibilities have not been examined until recently. Although new filter-photocell methods for measuring color have been announced frequently during the last 15 years, measurements have shown that the filters and photocells in most of these instruments were not properly chosen, as regards spectral character, for making the purported measurements of color.

In *Circular C429* of the National Bureau of Standards, Richard S. Hunter describes a number of types of color measurements which can be made with any device having the source, three filters, and photocell which he has selected. Because the resultant three combinations of source, filter, and photocell are nearly equivalent spectrally to the ICI standard observer for colorimetry, measurements with them give valuable quantitative color information.

Copies of *C429* are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

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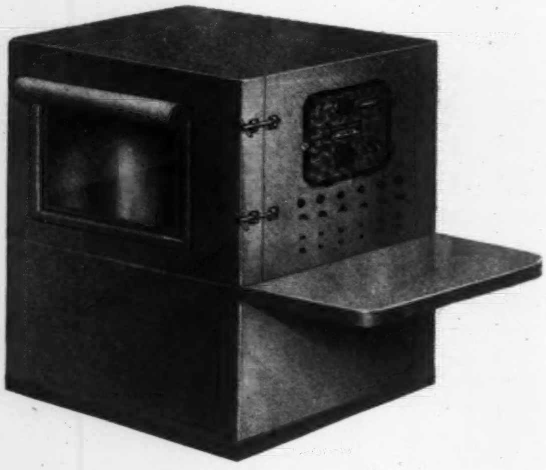

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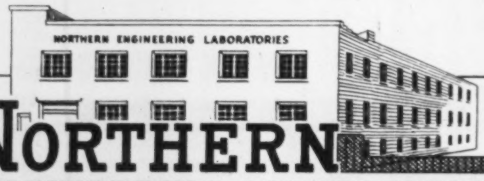


NORTHERN
ENGINEERING LABORATORIES
50 CHURCH STREET · · · NEW YORK, N.Y.

Instrument Pivots and Bearings Go to War

(Continued from Page 266)

in the form of full-length technical papers before various engineering bodies.[1] This will require that competent writers close to the scenes of action start gathering quantitative data from their associates and competitors, or—in many cases—obtain such data by making new tests and devising new test methods. Statistical information likewise requires diligent delving.[2]

1. *Shifts in Research Intensity and Direction*

So much research on pivots and jewels of precision instruments has been carried on since the turn of the century that the published research alone represents a bibliography of more than 500 primary references and, depending on the compiler's selectivity, from 1000 to 3000 other titles—all on pivots and jewels of *precision* instruments. By this we mean that these are reports of research always aimed at the further refinements of high-sensitivity laboratory instruments, while on the other hand a scant half-hundred brief articles reported all the original research that was devoted specifically to the pivots and bearings of industrial service instruments subject to rough usage—to what nearly all of us authors, through force of habit, still term "abuse."

At first glance, this ratio of 500 to 50, or of 3000 to fewer than 50, justified the inference that research has been woefully misdirected. Caution dictated taking closer looks before making this accusation.[3] It seems that no single group can be blamed for not numbering a prophet[4] in its ranks. Admirably thorough research was done on what now seems a minor case but was then of real practical importance; the specific problem of the precision electrical laboratory instrument with *vertical* shaft.[5] The revolution is

---

(1) Or in the form of articles in technical magazines whose scopes cut across the boundaries of the distinct engineering fields.

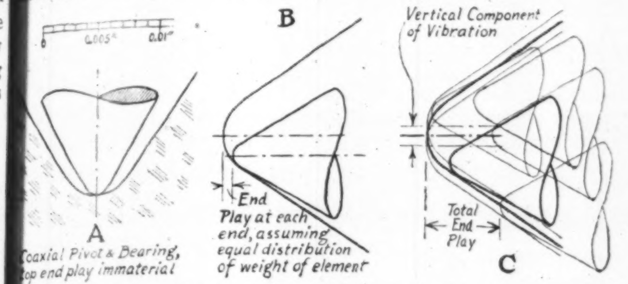
(2) Certain nationally-consolidated figures to which a writer can have access in Washington are not for publication and were compiled for other purposes. For example, figures on types of instruments for the Armed Forces have their classifications based on other things than designs or materials of pivots and bearings. Similarly, the obtainable sales and shipment figures from a few suppliers of raw and finished materials of specific interest threw little light on the actual totals or proportions of instruments employing various types of pivots and bearings destined for the Armed Forces: A recent sudden increase in the demand for one product might mean building up supplies of spares because the item does *not* stand up; or it might mean that the item has been found *superior* and is being ordered in quantities to replace one that has proved inferior. Nevertheless, although a quantitative report must be postponed, the qualitative analysis made possible prove beyond doubt that the revolution is well under way.

(3) It has been edifying to glance through some thirty of the books and articles—those that were at hand, but a representative sample because they did not merely *happen* to be at hand. One finding (expected, of course) was that the ratio is the average for the entire half century and has not been constant: in the last decade, between a fourth and a half of the published research took account of severe service conditions. Another finding was that most "purely laboratory" research projects before the 1930's contributed indirectly to the betterment of "service" pivots and jewels. Another unexpected finding was that even when the research *work* was for the laboratory applications, many of the *authors* were evidently conscious of severe service conditions. In general, authors reporting their own latest work were too brief and those preparing correlations of data discussed the implications.

(4) Only a prophet could have foreseen an airplane equipped with a hundred instruments, or a mobile television transmitter, or a pocket exposure meter, or any of the dozens of different portable testing outfits with several indicators on the panel-board, or, for that matter, the modern panel-boards serving hundreds of different purposes but all subject to vibration.

(5) In English, German, French and American technical journals there were numerous articles on the value of the torque-weight ratio and later on the value of the exponent in the rationalized torque-weight equation; on the causes of variations in the coefficients of starting friction; on pivot-point and jewel-bottom diameters to obtain optimal normal-load contact area; formulas for effect of pivot-point deformation on friction torque; etc., etc. These problems engaged the attention of such authorities as Brooks, Stott, Keinath, MacGahan, Edgcumbe, Goss, Stickney, Carson and many others. The classic in this field is Verney Stott's "An Investigation of Problems Relating To the Use of Pivots and Jewels in Instruments and Meters," National Physical Laboratory (Teddington, England), 1931.

full swing now, but it began in the mid-thirties when rkers long accustomed to think in terms of A began to rk on B and to consider C (which is a visualization of ntinued vibrations and occasional shocks as essential elents of the problem). Now, of course, workers realize at the problem challenging their genius is that of the rizontal-shaft instrument exposed to vibrations and ocks—exemplified by the sensitive altimeter which must expected to get kicked.[6]


0
0.005"
0.01"
A
oaxial Pivot & Bearing,
op end play immaterial
B
End
Play at each end, assuming equal distribution of weight of element
Vertical Component of Vibration
Total End Play
C

2. Pivots

) Steel

The physical properties of various steels are too well own to need summarization or comment here. Of the nctional characteristics as a pivot material, corrodibility the worst but it seems that some authorities think it can cured or greatly reduced by "a high degree of polish."[7] ittle is known of the effect of polishing on "micro-elasticy"—the elastic deformation characteristics which deterine contact area under load, though it is known that lishing raises surface temperatures momentarily to above 00°F. It may be said that the "extreme radicals" of this volution are the ones who want to do away altogether ith steel pivots. At present, on a numerical basis, hardned high-carbon steel pivots still predominate and are still ecified but "substitutes" are allowed in an ever-increasing roportion of the specifications. Steel pivots are *not* used numerous aircraft applications, in some vitally impornt Navy applications and in some interesting Ground orces applications including secret detection devices.

b) Non-corrosive Alloys.

These are alloys of rare metals of the platinum group platinum, rhodium, palladium, osmium, iridium and uthenium) in which osmium is believed to predominate. he pivot "blanks" or "pellets" are produced by sintering. dvances in powder metallurgy, plus special research by e pivot manufacturers, have made possible fairly close ontrol of the desired properties and the elimination or inimization of undesired characteristics.

For further details we quote spokesmen for the two manfacturers who at this writing dominate the field of noncorrosive alloy pivots:

"Permo" or "Permometal" Alloy. "The results of standrd vibration tests, frequency of 1800 cycles per second ith an amplitude of approximately 0.020" are as follows: adius 0.002", microscopic inspection shows no wear after 00 hours. Radius 0.00075", slight wear at 50 hours. Compared to steel pivots on dry tests Permopivots give at least wenty-five times longer life. Permometal is non-ductile. fter alloying, it is broken and sized into small pellets. roduction requires welding of the Permometal pellets to suitable shank material—magnetic or non-magnetic—fol-

---

(6) Unbelievable? Verified beyond doubt by ground crews reporting cracked dial glasses and many a brave airman confessing Yeah I know better but when I've got to have an exact reading can't help giving 'er a little tap just to make sure she isn't sticking. You'd do the same when the game is for keeps!" An il pressure gage can take it but *it* never has to: the more sensitive the indicator—and hence usually the slower—the more it gets kicked.

(7) The latest War Standard on instruments (C39.2) requires that "All metal parts shall be of corrosion-resisting material or of a material treated in an approved manner to render it adequately resistant to corrosion," but adds that "A high degree of polish on hardened steel pivots will be considered as satisfactory protection of these parts."

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lowed by grinding and polishing to specifications. This is a skilled operation perfected by thirteen years of experience."[8] "We are often asked 'What is the hardness of Permo Alloy?' Hardness is usually given in Brinell or Rockwell numbers which expresses the metal's resistance to deformation, but does not necessarily give a true indication of its resistance to wear. Take for instance, two phonograph needles, one of steel and one tipped with Permo Alloy of approximately the same Rockwell hardness, and we will find the ratio of wear to be of a magnitude of 1,000 to one. . . . Steel, or similar material, . . . gradually burns away. Permo Alloy, . . . with a fusion point of over 4000°F. is merely rendered semi-plastic which enables the point to take an extremely high polish. This . . . is of the utmost importance in instrument pivots where an accumulation of the products of wear (rust) in the bearing will cause an increase in friction."[9]

"Paraloy" and "Permium" Alloys as Used in "Aeropoint" Pivots. "The Paraloy group of alloys, including Permium and Permette, are available in various forms. . . . Usually a requirement is smootness and anti-friction. The components . . . combined to provide an improved alloy which requires no lubrication and in which the molecular structure is homogeneously heterogeneous . . . controlled in manufacture so that . . . alloy is produced whose microstructure has . . . the same polyhedric structure in any direction. Permium alloy eliminates micro cracks which occur in most alloys and metals due to the crystalline formation on cooling. . . . no soft binders are used, . . . thus eliminating the possibility of the wearing away of finite particle sizes. . . . The binder in Permium sintered alloys is of precious metals and is carefully selected for each series of alloy designed for specific applications. . . . Physical properties (of one type of Permium) . . . Rockwell 'C' hardness 60 to 65. Mohs hardness 7.5. Melting point 2750°C. . . . surface becomes 'super smooth' when working under load . . . resistance to abrasion . . . wear resistance even when working with dust or abrasive particles present. . . . Corrosion-proof . . . inert to acid or alkaline solutions to as much as 20%. . . . Anti-friction . . . instrument application a pivot tipped with Permium . . . gave a 50% decrease in friction over steel. . . . In aircraft instruments . . . no increase in friction after abuse tests designed to excessively wear the tip."[10]

3. *Jewel Bearing Materials*

(a) Diamond

Diamond is the hardest material known to man. Its wear resistance and abrasion resistance are also the highest. Though not insoluble, it is not injured by such acid or alkaline drops of atmospheric condensation as may form inside an instrument case in tropical climates. It is polished by diamond dust and this process may be carried on with finer and finer dust until the roughness is so small that the pen of a high-amplification smoothness recorder draws a smooth line. In other words it is *practically* "perfectly" smooth although the polished surface of any crystalline material is rougher than that of some amorphous frozen substances. In nature, diamonds occur as single crystals. The structure is cubic. When a surface is not a crystal plane, scratches and cracks are jagged and, even when microscopic, damage smooth metal surfaces more quickly than could similar irregularities in the surface of any other material. Although diamond is the most *durable* bearing material, it cannot be said to be the *best*.

(b) Natural Sapphire and Ruby

These natural forms of corundum are second to diamond on the Mohs hardness scale. On the various scientific scales their hardness "number" is likewise "close" to that of diamond. It is not amiss to mention that there is no such single property as "hardness." Various measures of various hardesses are obtained by some twenty different methods developed by mineralogists, metallurgists, physicists and other investigators: scratch, indentation, penetration, grinding, ebound, etc., etc. Most methods agree in assigning to corundum second place in all these and also in methods for etermining wear resistance, abrasion resistance, local impact strength, etc. Sapphires polished by diamond dust take "perfectly" smooth finish. Cracks, etc., abrade metal pivots lmost as rapidly as do cracks in diamond.

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[8] From leaflet issued by Permo Products Corp., 6415 Ravenswood Ave., Chicago, Ill.

[9] W. H. Falck. "What Is An Instrument Pivot?" *The Instrument Maker,* Vol. 9. Nov.-Dec. 1941, page 6.

[10] From bulletin issued by The Paraloy Co., 600 South Michigan Ave., Chicago, Ill., and in small part from a private communication from its Chief Engineer and General Manager.

(c) Synthetic Sapphires

Like the natural corundum, these are next to diamond on the Mohs scale, but it is claimed that the new synthetics made for instruments are among the hardest of all types of synthetic or natural corundum. "White sapphires, which are the desired industrial product, are crystal-clear, being pure aluminum oxide (Al_2O_3). To facilitate cutting, each boule is split longitudinally before shipment. This operation releases locked-up stresses and assures that the material acquires its normal good resistance to shock."[11] Production was reported last November to have reached a volume sufficient to satisfy the war demands of all the United Nations.

Because diamond and various types of corundum are extremely hard, the shaping of the vee cavity is a difficult operation. A certain instrument factory is reputed to be the home of the most zealous advocates of sapphire against new materials, but it was one of the engineers there who wrote: "A visual inspection will show equal and satisfactory polish on all important surfaces. Yet one instrument may show a frictional torque several times that of the other. This difference arises from differences in contours of pivot and jewel. In grinding sapphires, a perfect cavity contour is the exception rather than the rule. The contour of a jewel cavity can be readily determined by forcing a soft wax or lead point into it under pressure, and examining the resulting impression under high magnification. Such studies have been made covering many thousands of jewels, and no two cavities are ever found exactly alike. Both flank angle and cup radius vary considerably."

(d) Rare-metal Alloy

"Permette" is one of the "Paraloy" group of corrosion-resistant rare-metal alloys, of which others were described under "Pivot Materials." It is claimed[10] to "offer heavy-duty bearings for heavier loads than sapphire or ceramics." Its surface is said to become "super smooth" when worked under load.

An obvious disadvantage of metal bearings is that they cannot be used as insulators. Their conductivity is immaterial, however, non-electrical instruments and even in the majority of *types* of electrical instruments.

(e) Glass

The heading should really be "glasses" because there are several, but the different compositions have not been made public, so that "instrument-jewel glass" would seem to be a satisfactory generic designation despite the avoidance of the word "glass" in the longest technical-journal article[12] on this subject. Although mass production did not get into full swing until 1941, many millions (we must not be too specific) of glass bearings are already in use. On the whole they are fulfilling the claims made by spokesmen for the two instrument companies which pioneered in this field. So much has been published in the technical press on these new glass bearings that relatively brief abstracts (not word-for-word quotations) can suffice:

"An instrument jewel and pivot function coöperatively. The hardened steel pivot is slightly harder, and hence the glass bearing is subject to failure first. A pivot used with sapphire is much the softer of the two parts, and hence is subject to failure. Functionally, there is a slight practical

---

(11) Anon. "Domestic Synthetic Sapphires." *The Instrument Maker*, Vol. 10, Nov.-Dec. 1942, page 10. (Describes new development by The Linde Air Products Co.).

(12) F. K. McCune and J. H. Goss (General Electric Co.). "A New Jewel for Indicating Instruments." *Transactions A.I.E.E.*, Vol. 61, Sept. 1942, pages 673-676.

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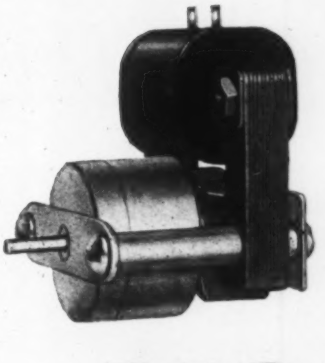

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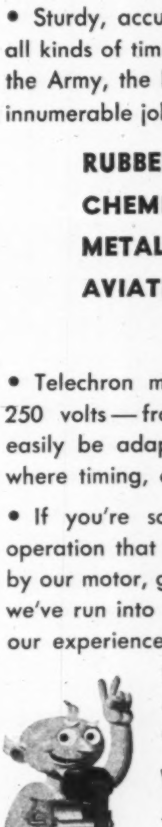

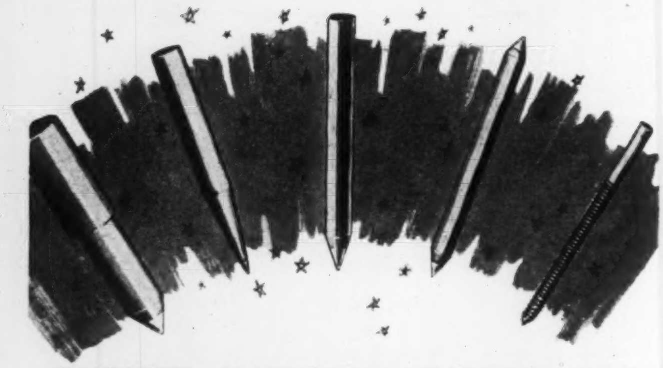

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advantage in having the jewel fail first, because it is more easily replaceable in the field than is the pivot.

"Glass bearings have the advantage over sapphire in that their cavities are controllable as to size and shape. Glass properly handled requires no polishing—an operation to be avoided due to rouge left in minute crevices. Glass does not wear down the pivot, thus preventing the movement from becoming 'loose in the jewels.' Glass does not tend to produce iron oxide or rust in the bearing cavity.

"It is not conceded that one gram is the maximum permissible weight of moving systems to be used with glass jewels as it is expected that further study of the larger size bearings will result in equally satisfactory results."[13]

"Substitute for sapphire . . . by quantity production of a hot-formed vee jewel with characteristics superior to those previously available. The requirements . . . (1) An almost perfect geometrical shape and one that can be controlled within narrow limits on large scale production. (2) Smooth surface and low coefficient of friction to hardened steel or alloy. (3) High impact strength. (4) Satisfactory life under conditions of vibration; should be at least comparable with sapphire. (5) Quantity production with due regard to economics of situation. . . . A thorough investigation of recent progress in high-strength glasses led to process of hot-forming one of the modern materials as the best answer.... The following tests were made: (1) Impact resistance. (2) Wear after a million pointer oscillations. (3) Wear in instruments under conditions of vibration. (4) Coefficient of friction using high-carbon steel pivots. (5) Actual impact tests in instruments." [Test results, given in tables and graphs, show glass bearings superior on the whole for the *miniature* instruments used in tests. Most conclusive finding seems to be summary of results of two-stage tests: vibration tests followed by friction tests.][14]

4. *Non-interchangeability*

The situation justifies the prefix "non." This is natural because of lack of national standardization in this field and because of the physical properties of new materials—not only as these properties affect dimensioning for best performance but as they affect dimensioning for mass production. It may well be that the three or four major categories of materials will each have its own dimensions and contours, thereby making difficult the *replacement* of a sapphire bearing, for example, by a glass bearing which at present has a diameter some 50% larger and therefore requires a larger jewel screw. This in turn necessitates reaming and re-tapping the bearing supports, using larger locknuts and spring washers, enlarging the hole in the zero adjuster, etc.

Glass bearings have been standardized by a WPB Subcommittee but the Standard is not yet in print at this writing. It will standardize sizes, tolerances, master gages, inspections, finishes, polishes, etc.

5. *Rolling-contact Bearings*

Of the various types and numerous forms of rolling-contact bearings used successfully in machinery, only the ball type is manufactured especially[15] for instrument applications. It has already been discussed in a general way in Section III.

Radial miniature ball bearings, for constantly-rotating instrument shafts, were the first to appear. The special form for pivots was perfected between 1936 and 1941 and its development is still under way. Only a month before this writing, there came in the mail an announcement[16] of "the smallest ball bearing in the world, with an outside diameter of approximately the size of one of the balls in our No. 2 bearing." (This would make it about 0.03" O.D. and each of the three balls about 0.01".) Pivot bearings are usually designed for 60° pivots. The number of balls varies from three up, according to size. Balls are described by one manufacturer as "chrome grade 1" (no doubt chrome steel) with tolerance of 25 millionths of an inch.

---

[13] A. T. Williams (Weston Electrical Instrument Corp.). "Glass Instrument Bearing Jewels." *The Instrument Maker*, Vol. 10, May-June 1942, pages 2, 4, 6, 8, 18.

[14] J. H. Goss (General Electric Co.). "A New Jewel for Electric Instrument Bearings." *The Instrument Maker,* Vol. 10, July-Aug. 1942, pages 2, 4, 6, 8.

[15] "Especially"—for it is true that *roller* bearings of the smallest sizes made by Norma-Hoffman are used in some instruments.

[16] From Miniature Precision Bearings, Keene, N. H.

Use of light instrument oil is recommended. Dry running is said to be "easily possible where required by temperature, etc."

Maximum loads (thrust, radial and combined) are listed for various high running speeds. For speeds under 1000 r.p.m., these loads are of the order of ounces.

V. THE IMMEDIATE FUTURE

When it comes to predictions of things to come, one man's guess is no better than the next man's—unless he stands on firm ground. The firmest ground is the witnessing of the shaping up of events. In technology, events are largely shaped by needs. If we look around and take note of all the things that should be done, it becomes an easy trick to forecast some of the things that will be done.

There is the need of a common language. Different workers use different terminologies, particularly in naming properties of materials and of parts made of those materials. The names themselves do not matter much, except when they give rise to confusion between, for example, the man who makes a material and the man who uses it functionally. The brief broad dictionary definitions do not define such terms as "wear resistance," "impact strength," "hardness," "micro-hardness," "elasticity" and "microelasticity" and even the engineering definitions in vogue in some other fields do not define them closely enough for this field. The immediate future should see the coining of good special-meaning names[17] and the formulation of definitions of such properties in quantitative terms. Agreement should soon be reached on the testing instruments and test procedures whereby the degree to which a material possesses a given property can be reported as a number and a name.[18] The National Bureau of Standards, the ASTM and the ASA being only too eager to serve as meeting-grounds, something is sure to be done soon.

Next will come the scientific correlation of physical properties and, perhaps, some surprises: diamond—its very name now magical—might no longer rate tops.

This will lead to classification of materials, their official designations, etc, etc., as in the steel producing and consuming industries where "SAE" or "NES" followed by a numeral means a material with properties listed in readily-available references. Instrument people will not do it by themselves; they will be represented on central committees.

---

(17) In the same detailed manner as G. W. Scott-Blair at the University of Reading has done for the essential rheological properties: "1. Viscosity; 2. Elasticity (since Poisson's ratio is taken as 0.5 throughout, only one modulus, the shear modulus, is considered); 3. Elastic fore- and after-effects and hysteresis; 4. Fall in viscosity with rising stress ("structural viscosity"); 5. Tendency of material to show a yield value, i. e. sharpness of curvature of viscosity-stress curve; 6. Fall in viscosity or consistency produced by shearing (a) non-recoverable, and (b) recoverable in finite time (thixotropy, false body); 7. Hardening produced by shearing (work- or strain-hardening); 8. Rupture properties." Needless to add, this basic list is only the beginning for "Viscosity" and others.

(18) In the manner which has proved so satisfactory in actual practice in the field of hardness measurements where we have not only "Brinell," "Rockwell," "Diamond Pyramid," "Monotron," "Herbert," "Vickers," etc., each meaning a class of testing instruments, but even divisions such as "Rockwell Superficial" and subdivisions such as "Rockwell Superficial 45-N Scale"—every name being preceded or followed by the scale reading obtained as the result of a standard test procedure. All these, by the way, refer only to the penetration class of hardnesses—none refers to the various wear-resistance and abrasion-resistance classes and types and varieties of hardnesses!

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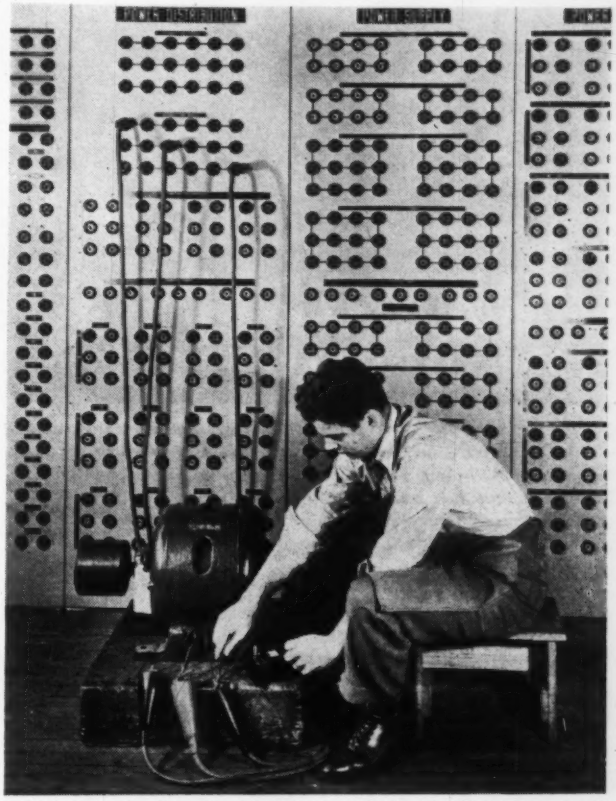

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The need existing, it is safe to predict modernization and standardization of tests for performance characteristics of parts (as distinguished from properties of materials).

Same for performance tests of assemblies. Tests on vibrationless laboratory benches will be supplemented or replaced by tests on vibration tables, as several engineers have already mentioned in their reports on glass jewels, alloy pivots, etc. [8, 10, 12, 13, 14]

There is need for standardization of shapes and sizes. Since the conventional design is so widely used in nonelectrical aircraft instruments as well as in its native habitat, and since the WPB is concerned, some of the items made in the largest quantities may already have been standardized to some extent by the time this article is sufficiently whipped up to be sent to the printer.

Simplification being a crying need, it is sure to come.

Experimentation with new materials is not "coming" for it has long been with us. What is coming is *daring* experimentation.

The same for experimentation with new designs and also with old designs from the horological hall of fame: for example the combination of a ring jewel and a flat (or slightly convex) jewel.[19] Watchmakers call it an "end stone."

The immediate future will certainly see definite (and definitive) quantitative answers to some phases of the eternal optimal-contact-area question emerging from the haze of speculation into the sphere of practicality as a result of the recent almost-simultaneous publication of an extraordinary number of papers on frictional phenomena, none rehashing old stuff, all contributing to clarification of ideas, some announcing "discoveries" rather than routine "findings," and some of these discoveries staggering many of us out of our smug reliance on classic formulas, particularly in the field of greatest interest, that of loadings involving unit stresses close to yield points, where the hypotheses of interpenetration and the influence of bulk properties have become facts supported by startling photographs taken by radically new techniques recalling the motto "The difficult we do today; the impossible takes a little longer" (or words to that effect).

The immediate future should see the appearance of bearings with a safety-factor design or dual-purpose design: "dangerously" low friction at normal loads, but absorption of shocks by other parts. In machines the analogous problem has been solved but the designs are too complicated for miniature reproductions in mass-production instruments. The solution will be as simple as the protected-diaphragm pressure gage but with the requisite dashpot function of the machinery protectors to prevent rattling.

Finally, it is safe to predict that the recognition of continued vibration as an ever-present condition will lessen the worry over starting friction. Starting friction is what makes us use filamentary suspensions instead of pivots for the coils of laboratory galvanometers but it certainly plays little part in the performance of the indicators in a tank or corvette. In fact, we'll make a new blessing out of an old evil by using designs and materials for low running friction, however high their stiction on the vibrationless laboratory bench. In horizontal-shaft indicators, the rust-particle and jewel-grit accumulation bugaboo is minimized by vibration.

PART TWO (FOR MAINTENANCE PERSONNEL)

VI. First Steps—Cleaning and Inspecting

The remainder of this article consists of practical notes on the *field* repair or replacement of instrument pivots and bearings. These notes have been compiled for users who lack the elaborate special equipment of instrument-company repair departments. It must be borne in mind, however, that pivot and bearing repair and replacement work requires a

---

(19) With conventional-design pivots and bearings, serious damage to *both*—at *both ends* of the shaft—results from excessive tightening, even momentary, when adjusting end play. Separation of the thrust function by the use of two end stones would end this cause of ruined pivots and bearings.

gh degree of skill. The notes which follow are not meant r persons without any experience in watchmaking or milar fine benchwork. Such persons, if assigned to the b of repairing pivots and bearings, should first read up ny good watchmaking manual and give themselves some reliminary practice. Moreover, these notes are for peronnel of instrument repair shops with at least the minium equipment of mobile units: a bench lathe of jeweler's ype or equivalent is one of the essentials. As in many ther lines of work, only an extraordinary degree of skill n take the place of the proper tools.

The following notes are for the information *and guidance* f personnel in civilian industries; and for the information f personnel in the Armed Forces, whose guidance in some f the procedures described may already be covered in some echnical Manuals or Training Manuals. This is the first t of notes of its kind and the writer offers it as a source r the preparation of special TM's.

Although pivot and bearing troubles are the commonest, t is wrong to assume that all instruments received at your hop need new pivots and jewels. Time is too precious to o a complete job on all instruments. Even a tag marked P & J" probably represents a guess rather than a valid onclusion. On the other hand, in every shop where damged pivots or bearings are found in a large proportion of nstruments received, it would be well to make it a standard outine that every time an instrument (even a fairly new ne) is opened up for any reason, a few minutes should be evoted to carefully inspecting its pivot points and its earings. It should always be borne in mind that microcopic damage to ordinary pivot points begins almost at the oment that an instrument is shipped out of the factory. f a new instrument in its original wrapping has been ropped before being installed, the injury to its pivots may e worse than the result of years of normal use.

In order to inspect pivots and bearings, there are three ssentials:

(1) Cleanliness—no film or anything else that may coneal defects;

(2) Good light and adequate optical magnification;

(3) Eyes that understand what they see.

1. *Cleaning*

In the U. S. and in the larger bases overseas, instrument ashing machines are available. These machines have eached a high state of development. Their efficiency, howver, depends on their being used in accordance with direcions. Of particular importance is the correct sequence of he prescribed washing and rinsing solutions. If the recommended trade-name solutions are not available, only approved substitutes should be used. In the absence of instrument washing machines, or if the supply of special liquids as run out, pivots and jewel bearings may be cleaned with he use of various pure alcohols, ethers, etc., approved by he watchmaking trades. But keep such solvents away from *lectrical instrument coils!*

Absorbent cotton fresh from the package is the best rubbing agent. If not available, use a bit of soft cloth which is not only clean but free from invisible gritty dust.

For cleaning the vee cavities, the cotton may be wrapped on the tip of a slender sliver of soft wood. Some experienced workers twirl the wood in direct contact with the bottom of the vee and assert that this does not cause damage if done with skill. Never use a metal point: even a brass pin which is much softer than gems or glass may ause cracks in a smooth jewel surface and certainly will enlarge any cracks that are present. Up to a few years ago it was common practice in some shops to search for cracks with a sewing needle but today it is known that a needle can scratch even the hardest substance, namely diamond. A good jewel will be injured by a needle: the scratches will probably be invisible when first made but they will develop into real defects.

2. *Inspecting Pivot Points*

A magnifying glass of about 5-power, or a jeweler's loupe, is needed even by the keenest-eyed workers. The ideal illumination includes not only a good diffused lighting (no

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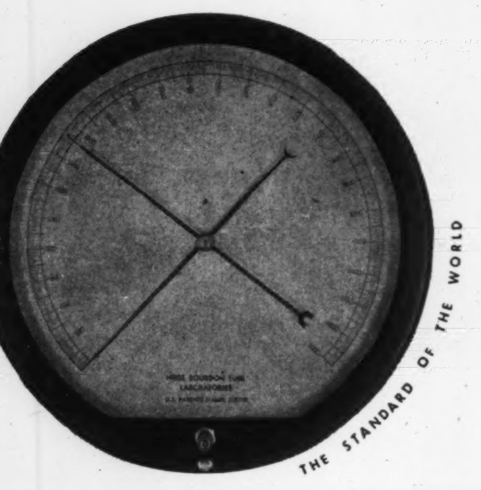

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unshaded ceiling bulbs to reflect a confusing pattern the ball point) but also *one* "point source" of light, such a frosted bulb. In a pinch, the single point source will but it is hard on the eyes. The pivot is inspected by twi ing it on its axis and by slowly turning its axis from si to side. Thus, defects which are too small to be seen d rectly will show up as momentary variations in the appa ent strength of the reflected frosted bulb. Do not twirl t pivot too fast, as a defect which obscures or alters t image of the bulb for less than 1/10 second will not detected.

The foregoing is for minimal-equipment shops; in sho provided with a microscope, that useful instrument will course be used instead of a loupe.

Beginners may be trained quickly by giving them, firs a pivot with a flat spot on the ball point: this flat surfa makes the image of the bulb larger and apparently brigh er, even to the naked eye, than the point image reflecte by a sphere. Next, give them a pivot with a crack not visib even under a 5× magnifying glass but large enough cut down appreciably the apparent strength of the r flected light.

This inspection will not discover microscopic cracks, som of which may be of such length that they would soon de velop into serious defects up to fractures, but a few mo ments' polishing will take care of all microscopic cracks To cure serious "flats," nothing less than a thorough re shaping or re-pivoting job will do. (These jobs are describe in a later section.)

Of interest to field workers, though written for personne in large utilities, is the following reprint* which the write has received from Mr. Henry Paulson, President, Henr Paulson & Co. (watchmakers, jewelers, optician's materials etc.), Chicago:

> Pivots after a thorough cleaning should be examined under microscope having a magnification of about 40 diameters. To high a magnification leads to confusion. Defects are considere under five classes:
>
> (1) Pivots with ends slightly flat, but burnished, for which th treatment is a slight trimming by revolving at about 2,000 r.p.m and using a piece of Arkansas slip, followed by polishing wit Hubert blue emery paper, or equivalent, starting with grade 0 an finishing with grade 0000;
>
> (2) Pivots with flat ends, showing concentric rings; these ar ground until concentric rings have been removed and polished a above;
>
> (3) Pivots unpolished and of bad shape, which are ground t shape and polished;
>
> (4) Pivots with pitted ends, for which little can be done, a pitting usually indicates unsuitable material;
>
> (5) Pivots with cracks in a highly polished surface. The latte indicates unsuitable material, the high polish is due to extrusion of metal forming a very thin skin which breaks away. The meta below is incapable of being polished by ordinary means. Th pivot point should be of hemispherical shape, and in no cas needle-sharp. The use of Diamantine or similar powders is no recommended, owing to the risk of small particles being left o the pivot and acting as an abrasive.

3. Inspection and Grading of Jewel Bearings

The following, though written for large utilities, is so instructive that we cannot do better than include it.**

"Three procedures are recommended and in each case the jewel has to be carefully cleaned, as a very slight film o grease or dust may obscure serious defects.

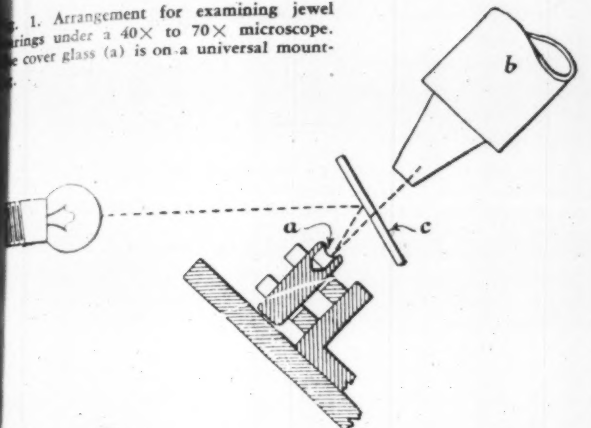
"The first method requires a simple microscope with magnification from 40 to 70 diameters. The microscope stage should be fitted with a means for holding the jewel coaxially with the microscope and automatically positioning it with the cup in focus. The jewel (*a*) (Figs. 1 and 2) is held below the microscope (*b*) in V-guides, so that it can be rotated and easily exchanged. The jewel is illuminated by a small 6-volt lamp, the light from which is reflected from a thin cover glass (*c*) carried by a universal mounting. By tilting the cover glass and rotating the jewel, the whole surface of the cup may be rapidly examined.

---

*From *Horological Journal,* London, England. The article in tha journal, however, is from a longer article originally printed i *Engineering,* London, August 29, 1941.

**This also is from the same source as the preceding quotation from the *Horological Journal.*

g. 1. Arrangement for examining jewel rings under a 40× to 70× microscope. e cover glass (a) is on a universal mount-g.



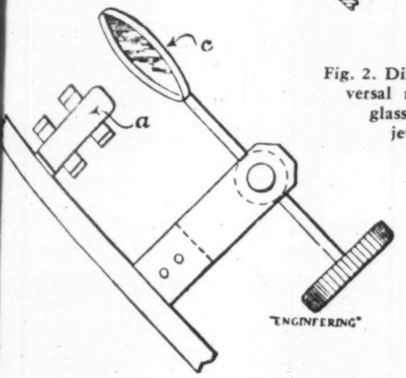


Fig. 2. Diagram showing the universal mounting of the cover glass shown in Fig. 1. The jewel-holder (a) is in side view.

"The second method uses a long-focus binocular microscope with magnification of 80 diameters. The jewel is held by the fingers in its mount and illuminated by a 60-watt pearl lamp in an anglepoise fitting. By focussing the image of the lamp and then closing in very slightly, the surface of the jewel shows up sharply. After short experience, the jewel can be rotated and focussed by the fingers at all angles without touching the setting of the microscope.

"The third method also requires a long-focus microscope, similar to that described above, but with the jewel (*a*) clipped in a holder keeping it in focus while permitting easy rotation (Fig. 3). Light from a 12-volt 25-watt lamp in the hood (*b*) and fed by a small transformer, is focussed by a condenser (*c*) and ground-glass diffuser (*d*) on to the spring-clipped jewel by means of a piece of mirror glass (*e*) set at nearly 45 deg. just outside the line of vision. This method shows up faults extremely well and is said to be superior to any other procedure.

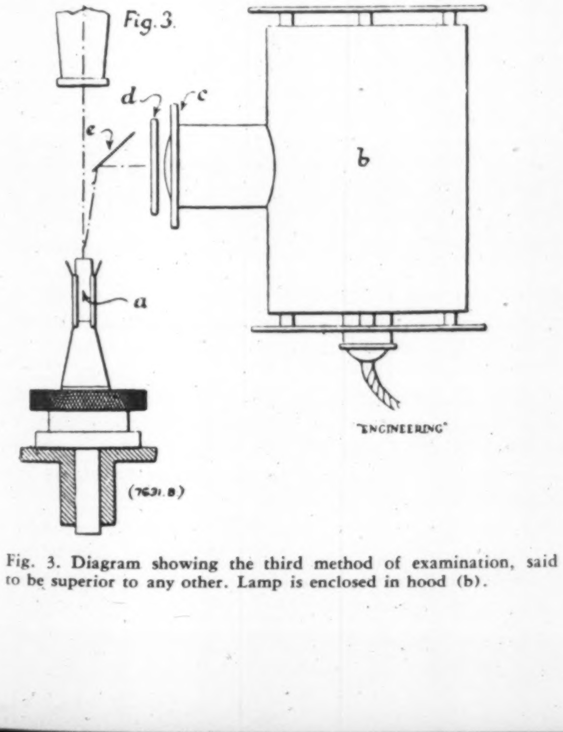
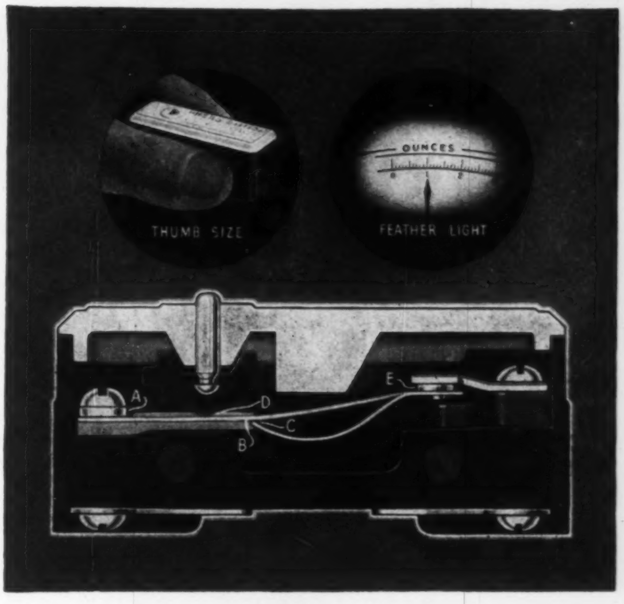


Fig. 3. Diagram showing the third method of examination, said to be superior to any other. Lamp is enclosed in hood (b).



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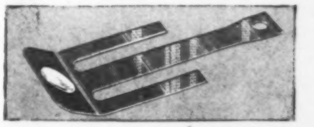
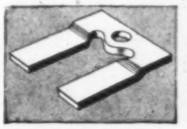


The beryllium-copper spring is made in one piece. It is gauged to an accurate .0085" thickness; has high resistance to fatigue. Ends of compression members are finished to provide an extremely low friction bearing. Contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. It moves at a speed of 3/1000ths to 5/1000ths of a second with a rolling action and extremely high pressure.



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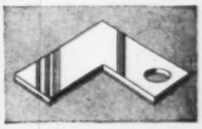

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If you would like to know more about the Micro Switch, send for the two Handbook-Catalogs illustrated here—No. 60, which covers Micro Switches in general; and No. 70 which deals with specific Micro Switches for use in aircraft.

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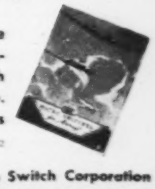

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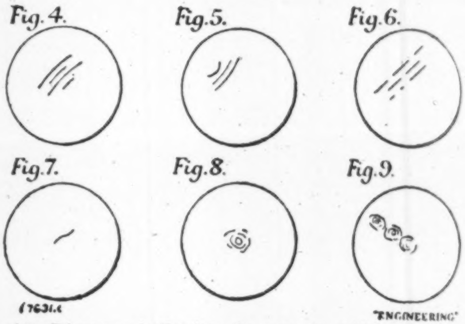
"Defects in used jewels consist in surface cracks, scratches and wear.

"Surface cracks, (Figs. 4, 5 and 6) when focussed, appea as sharply defined lines on the surface; when more tha one, they are parallel. A straight or curved appearance depends on the optical axis of the jewel.

"Scratches (Fig. 7) may come from the original polishing from debris or swarf impacted between pivot and jewe



Figs. 4-9. Diagrams indicating the way in which jewel surfaces show deterioration. Figs. 4-6 show surface cracks, Fig. 7 scratches and Figs. 8 and 9 wear under low and high loads respectively.

during transport; they differ from cracks, being less sharply defined and showing no clearly marked direction.

"Wear (Fig. 8) is found as a rounded area, approximately in the center of the cup, when the meter has spent most of its life at no-load or or at low loads. In meters which have run for long periods at high-load the rounded areas may extend outwards up the side of the cup (Fig. 9), due to displacement of the rotor system at higher loads. The deeper the wear, the sharper its boundaries.

"After examination the jewels should be placed in three grades: (1) those showing shallow central wear or scratches outside the possible working surface; (2) those capable of being re-surfaced, including those with moderate central or extended wear or with slight scratches within the working surface area; (3) rejected, *i.e.*, jewels with major defects, surface cracks, deep central or extended wear, or deep scratches within working-surface area. The grading is a matter of experience; surface cracked jewels are useless as they stand. Minute fragments may break off from the edges of the crack and, acting as an abrasive, cause rapid destruction of the bearing. The proper grading in the case of wear is facilitated by investigating jewel and pivot before and after cleaning. Very flat pivots, or a large amount of oxide indicates considerable wear, making a successful reconditioning doubtful.

"Views differ as to the desirability of retaining jewels and pivots in pairs. Some consider this inconvenient and unnecessary as long as the radius of curvature is about 1 to 4. The Meter Technical Committee consider it desirable to keep the components paired if the jewel is in the first grade, and acceptable for re-use, the same applies for the 2 and 3 grade, until the re-conditioning of the jewel has been decided." [End of quotation from *Horological Journal*]

In the foregoing reprint, the importance which the English instrument users attach to grading jewels is of special interest because no American organization has ever issued such detailed instructions. Soon after the outbreak of war in 1939, England faced an alarming shortage of jewels because her supply (from Switzerland) was cut off. At the same time, modern warfare meant an enormously increased production (and destruction) of instruments. That is why English industrial and military repair shops must salvage a greater proportion of unserviceable jewels than we do at present. That is why the foregoing reprint, representing a considerable amount of thought and research, is worth our studying.

A microscope is necessary not only for grading jewels into a number of grades but for determining which jewels should be replaced—the chief purpose of field inspection.

ot every instrument repair shop is equipped with a high-rade microscope, but many of those not so equipped are cated near a laboratory where microscopes are not in con-ant use. Industrial instrument departments can make ar- ngements with plant laboratories; Army and Navy base ops with base hospitals. To save trips, substitute good wels for all those removed and take the removed jewels at eekly or other regular intervals to the laboratory or spital.

Glass jewels seldom split or crack and Figs. 4 to 9 are ot all applicable. The nature of the commonest injury due impact is a "surface pulverization of the outer film, hich leaves a tiny rough spot." This spot is usually un- istakable because it is white.

In American instrument factories the preferred instru- ent for jewel inspection is the *binocular* microscope. If the olume of work permits the investment, it should be added. Even through the simple "shop microscope" that should e in every shop, *trained eyes* can detect and classify jewel efects better than the eyes of a novice through the costliest icroscope.

Good appearance (absence of surface flaws) is not all hat makes a good bearing. If the shape of the vee cavity as been seriously altered by wear, the jewel may be unserv- ceable. In precious-stone bearings (which are imported) he cavities have been ground in Switzerland and other European countries and are far from uniform even when ew. F. S. Stickney, a Westinghouse instrument engineer,

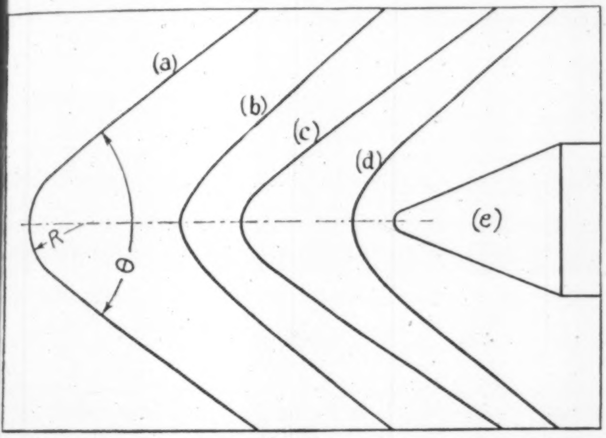


Fig. 10A.

(a) Hypothetical jewel cavity having true radius and truly conical sides.
(b), (c), (d) Tracings made from actual jewel cavities showing normal acceptable variations in contour.
(e) A theoretical pivot with truly spherical tip.

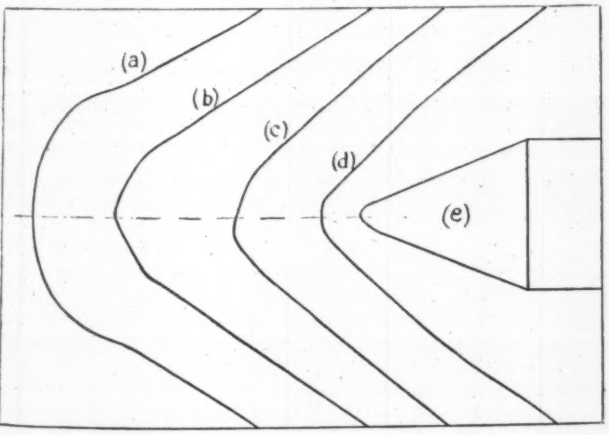


Fig. 10B. Tracings from actual jewel cavities, showing undesirable contours which must be eliminated by careful inspection in order to avoid excessive friction.
(a) Excessive radius and variable slope.
(b) Flat slopes near bottom of cavity.
(c) Unsymmetrical cavity with flat spot.
(d) Radius too small with bottom of cavity flat.
(e) An overloaded pivot, with spot worn "flat."

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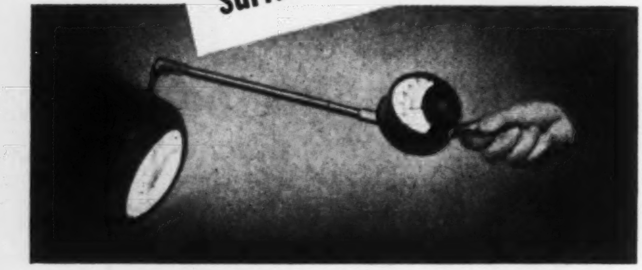

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reported investigating thousands of cavity contours by taking wax or soft-lead impressions and examining these under high magnification. Mr. Stickney had exact drawings made (see Figs. 10A and 10B). He reported* as follows:

"In Fig. 10A, (a) is a theoretical normal jewel cavity as reproduced by the skill of the draftsman. No cavity is ever like this. (b), (c) and (d) show *actual* jewel cavities with the necessary manufacturing tolerances on dimensions for radius R and angle θ. These cavities illustrate approximately the variations which must be accepted in order to obtain jewels in commercial quantities: reasonable tolerances in grinding sapphires by the best domestic and foreign artisans. In Fig. 10B, (a), (b), (c) and (d) are tracings made from actual jewels, showing some of the contours which, if not eliminated by careful inspection, will tend to produce excessive friction."

VII. Pivot Repair and Replacement

This section has been especially written for our readers by Mr. F. E. WILLIAMSON, Chief Engineer of The Paraloy Co., (manufacturing engineers, makers of "Aeropoint" alloy pivots, Chicago). He probably is the one who designed the world's first wear-resistant non-corrosive alloy pivots and bearings. In several letters to me during the last few months, he has repeatedly stated that he was preparing shop notes on alloy pivots only—not on steel pivots. Nevertheless, his instructions seem to cover steel pivots as well, giving many more details than any pivot repair notes ever published before.

Moreover—and this is important—Mr. Williamson's instructions apply not only to electrical instruments but to all Army and Navy instruments using alloy pivots: various aircraft types, radar sets, submarine detection sets, naval compasses, etc. —MFB

For the instrument mechanic to do a thorough and quick job of pivot parts repair, it is essential that he understand the fundamentals of the elements with which he is working.

In an effort to improve pivot performance and instrumentation, wear-resistant, non-corrosive "Aeropoint" pivots were designed to combat the various factors causing inaccurate instrument function, with the following specific objectives: (1) to eliminate steel or other materials which would corrode under adverse conditions; (2) to provide wear-resisting characteristics so that the pivot will continue to operate even in dusty atmospheres; (3) to provide shock-resisting ability; (4) to provide resistance against long periods of severe vibration; (5) to minimize friction. These five characteristics extend the useful life of the instrument and forestall costly dismantling and servicing.

Because of the high resistance of alloy pivots to indentation and also due to their peculiar microelastic properties, these pivots seldom break in the normal service of the instrument even when subjected to aircraft vibration.

Alloy pivots such as "Aeropoint," specially designed for instrument application, are usually made by welding to suitable shank material pellets of alloy made mostly from the platinum group of metals. Any of the alloy pivots should possess the five essential characteristics listed above.

There is a sixth characteristic which is desirable but not vitally important, namely, uniform appearance. Minute variations in the welding of the alloy tips to the shanks in the manufacturing procedure cause various production problems which the manufacturer usually overcomes before shipment of alloy pivots is made, but with today's battle of production, some pivots do slip through with slight variations particularly due to the welding operation. The instrument service man will realize that ordinary steel pivots are made of a single piece of stock: ground, hardened, and then polished. Alloy pivots, on the other hand, are composed (see Fig. 11) of a pellet A welded to a suitable shank B. Slight variations in the welding of the pellet cause slight bulging in the flowing of the material in the welded joint, as shown at C.

---

*Instruments, May 1935, pages 112-114.

In the manufacture of the pivot point, the end is ground as indicated by the dotted lines D so that in production, most of the swelled material section has been ground off. However, as previously mentioned, pivots sometimes are found in the field with a slight increase in diameter as shown at E in Fig. 12 which shows the finished pivot with alloy point F ground to the required cone angle and with proper radius. This pivot would work perfectly. However, the field service man called upon to service a damaged instrument may find that the slight bulging may interfere with the insertion of the pivot into his staking assembly mechanism. In servicing alloy pivots, the mechanic should remember this and, after examination through the magnifying glass, if this condition exists the pivot should be chucked in his lathe and excess shoulder material removed so that the pivot appears as in Fig. 13. He will then be able to chuck or insert the pivot into a holder for proper servicing or assembly operations.

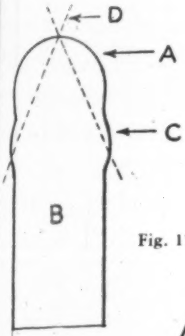


Fig. 11

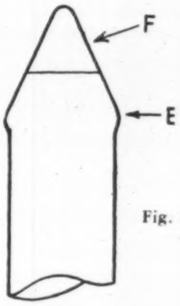


Fig. 12

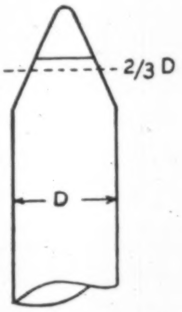


Fig. 13

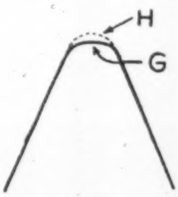
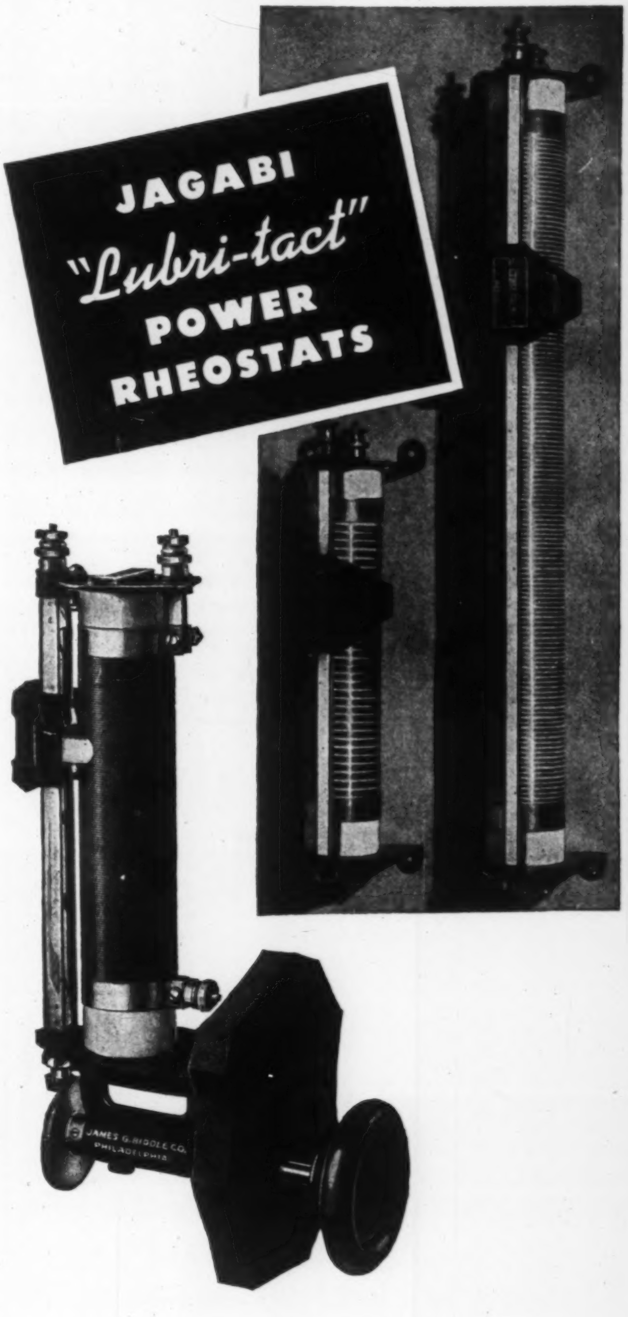


Fig. 14

Since this discussion is confined to the field repair problems of the service man, or attempt will be made to elaborate on various instrument servicing methods practiced in factories, but the mechanic should know more of the function of the pivot point when actually working under load. It can easily be understood that in a conical pointed pivot as used in most indicating instruments, with a tip radius of less than one thousandth of an inch, even with a pivot load of only a few grams the resultant stress per unit area on the pivot point will approximate many tons per square inch. Since the theoretical pivot point is a perfect sphere with extremely small radius which permits it to operate with minimum friction in the pivot bearing seat, it will further be understood that a loaded pivot point will no longer retain its perfect sphericity if the assembly is subjected to vibration abuse. Microscopically, the ball point of the pivot will have a temporary deformation similar to that of a rubber ball when dropped on the floor or a golf ball when struck with a club; that is, a deformation of the curvature of the contacting surface will occur as shown between the lines G and H in Fig. 14. Actually, then, at the instant of impact, the surface of the ball point has receded from a spherical shape H to an ellipsoidal shape G. This means that the materials composing the pivot point when subjected to vibration are alternately under contraction and expansion.

The work done by the ball-pointed pivot in its constant deformations when subjected to vibration would not be harmful to the shape of the pivot point if the elastic limit of the materials composing the unit is not exceeded and if the operation due to the torque and rotary motion of the pivot does not wear the pivot point materials. Actually, it



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is found in field service that considerable wear of the point occurs due to vibration and also due to the oxidized surface of steel pivots, which corrode and abrade in tropical atmospheres. The service engineer should understand that with the production of an alloy having improved corrosion resistance and wear resistance and also a surface hardness comparable to the hardened steel pivot, naturally the structure of the special alloy will be crystalline and although sintered metallurgical manufacture provides an alloy which is quite uniform in its microcrystalline structure, it still is on the brittle side. This is not unusual when one considers that ordinary hard lathe tool bits are brittle and their cutting edges do break when severe loads are imposed on them. It must also be remembered that alloy pivot points are ground to sharper angles than the angles of the hard machine-shop cutting tools. Thus the unit stress load on the pivot point material is extremely high so that alloy pivots should be handled with some care. The alloy pivot point, due to its crystalline structure, is relatively strong in compression but relatively weak in shear, which means that it will withstand greater vertical loads on the point section than it can possibly withstand from a shearing or side pressure at the point of the long slender taper. In servicing alloy pivots the instrument man may find that the point of a pivot that has been subjected to abuse may be broken in a jagged fashion as shown at *I* in Fig. 15. The following repair information naturally will apply to any pivot point, but we shall confine our discussion to alloy pivots.

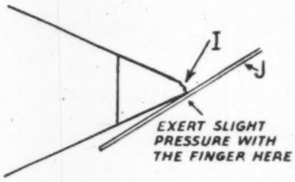

Fig. 15

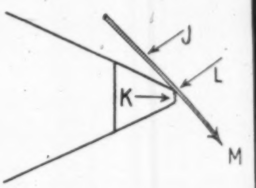

Fig. 16

In order to repair a pivot point broken as in Fig. 15, the pivot can be chucked in a lathe or other spindle and rotated between 200 and 500 r.p.m. A strip of No. 0000 emery polishing paper (*J*) between one and two inches wide and approximately ten inches long, should be placed on the underneath side of the pivot point and slight pressure applied with the right forefinger (if the mechanic is right-handed). The edges of the paper *J* are supported by the thumb and other fingers so that the left hand can then draw the strip of paper towards the body in a long, gentle, sweeping stroke. In order to bring the point back to a shape approximating a cone, several strokes must be applied in this manner. The operator should use a magnifying glass to closely check the results of the stroking of the point. Usually, only a small section of the tip is broken in service and it is not recommended that grinding or oilstones be used to try to service the pivot. It may take some "elbow grease" and stroking with the fine emery polishing paper, but the mechanic will have a better job when he is finished.

When the point has been stroked sufficiently to polish off the point section similar to *K* in Fig. 16, a different technique is now required to lap the point round and to a usable radius. The operator should hold the same strip of emery paper in both hands as shown in the multiple-exposure "action photo," Fig. 17 (which shows the repair of a large Navy compass pivot). The polishing paper *J* (Fig. 16) held in this manner is then stroked across the edge of the pivot point as at *L*. The direction of the stroking motion is shown at *M*. This operation consists of a *light* pressure of the paper on the pivot point. If the paper is pressed heavily against the pivot point, it will be found the resulting polished surface is not as smooth as that produced by a light-contact stroke. Fig. 16 is the beginning of the repair stroke and to properly service the point a series of rotary transverse strokes are necessary. It might be mentioned that sometimes on pivot points which have a relatively broken area, several straight strokes in direction *M* (Fig. 16) may

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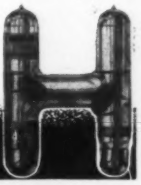

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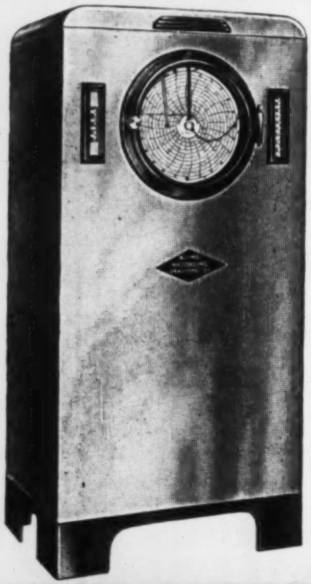

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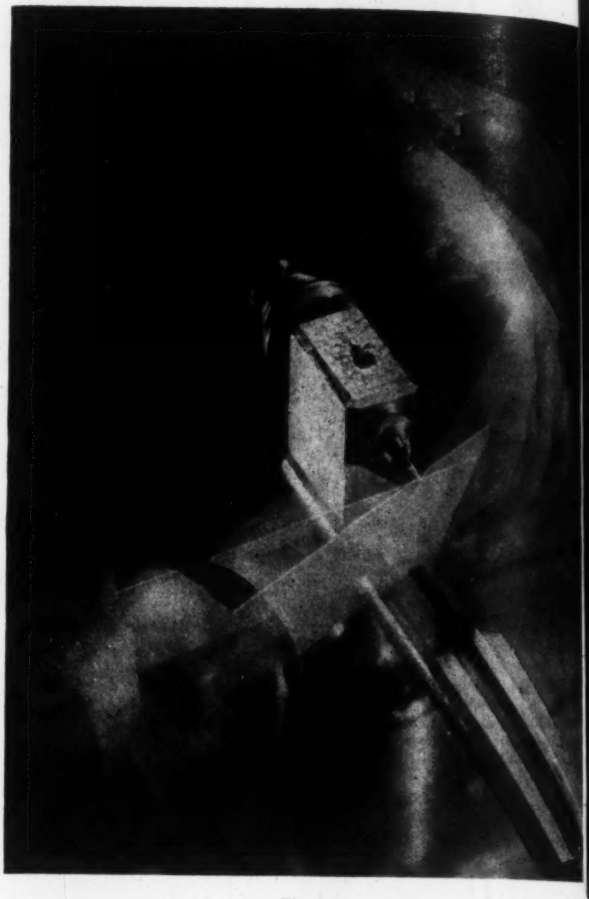


Fig. 17

be necessary if the operation in Fig. 15 does not restore the broken point to a reasonably straight section.

The transverse stroke motion is shown also in Fig. 18. Grasping the two ends of the polishing paper in both hands, the operator will run the lathe so as to rotate the pivot from 200 to 500 r.p.m. The speed is not critical, but high speeds should be avoided. The right hand will then gently hold the polishing paper against the edge of the pivot point, the left hand holding the other end of the paper so as to create a slight angle with the cone section of the pivot as shown at J in Fig. 18. The direction of the stroke is indicated by the arrows. The paper is then brought towards the operator in a long, gentle, sweeping motion so as to provide a constant stroke, varying the point of contact between the paper and the pivot itself. The proportion of the stroke and the contact area is indicated as the short section at the end of the paper N_2 at the start, and the beginning of the end of the stroke N_2, of the paper J in an arc as indicated by the arrows. At the instant that the rotary motion has brought the stroke to the position marked "*J finish*," the section of the paper marked N_1 which amounts to about two inches is then brought straight towards the operator so as to be at right angles to the axis of the rotating pivot. In other words, this sweeping stroke of the paper contacts the pivot

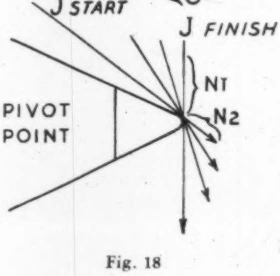


Fig. 18

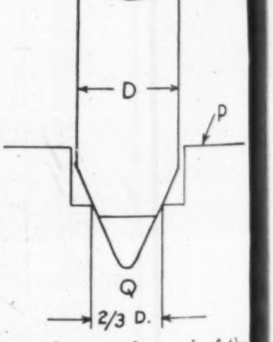
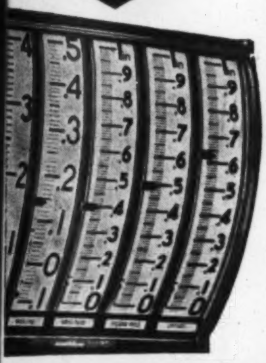


Fig. 19

THIS DRAFT GAGE

GAGES DRAFT



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point with a length of paper approximately ten inches long in a semicircular motion so as to provide a rounding off action on the point, the finish of the stroke providing about two inches of the paper for polishing straight across the end of the pivot. This last part of the action is very critical and care must be exercised not to exert any pressure on the pivot point because after several operations the operator may find that he is flattening off the end of the pivot rather than rounding it off.

This procedure will restore the radius of any pointed pivot. From two to thirty rotary stroke motions may be required to restore the ball point to the pivot, depending upon the size of the damaged section of the tip. Usually a series of very light strokes will be better. It must also be remembered that the number of strokes will govern the size of the radius of the point. If the operator has healthy arm muscles and he continually makes the radius too large, then the polishing paper should be rubbed on an oilstone rather briskly so that the small abrasive particles are reduced in size so that they will have little cutting action. This will enable the operator to apply the required number of strokes without whittling the point to an unusable stage. The importance of a light contacting pressure of the paper on the point cannot be over-emphasized. The motion of the rotary stroke need not be slow. In fact, if the operator can make a quick and fast stroke with light contact pressure, he will be able to produce a highly polished surface.

On some assemblies it is necessary to remove the pivot staff to repair the point. The operator should carefully check the shoulder of the tip section (E in Fig. 12) and with his micrometer make sure that there is no burr at this place which would prevent a free staking operation. In the staking operation many alloy pivots have been damaged because the operator did not realize that alloy points must be provided with a relief so that no pressure is exerted upon the point itself. This is diagrammatically shown in Fig. 19. A reliable guide is to provide a relief section for the tip equivalent to two-thirds the diameter of the pivot staff as outlined in Figs. 13 and 19. This will then provide a clearance between the staking anvil P and pivot staff D. The size of the clearance hole Q is not particularly critical so long as it is large enough to adequately protect the pivot point in case the pivot staff shifts slightly from a vertical axial position in the staking operation.

Section VIII, on Effects of Vibration, will appear in the next issue

---

ELECTRON TUBES

(Continued from Page 260)

field in which it is placed and it will be drawn toward the positive pole of that field. This is merely another way of saying that an electron is attracted by a positive charge.

Fundamentally, an electric generator consists of an arrangement whereby a moving magnetic field is made to cut groups of conductors. It can also be shown that a moving magnetic field creates an electric field and it is this electric field which sets the electrons in the conductor in motion. When the generator is set in motion the electric field produced between the terminals of the machine acts upon all the electrons in the circuit and they all start to move at once in the direction of the positive terminal. As long as the generator is kept in motion, the free electrons in the circuit will continue to circulate.

The number of electrons involved in the conduction of current is enormous, though it may be found by simple calculation. One ampere of electricity, for example, is defined as the flow of one coulomb of electricity per second past a given point in a conductor. Since the charge on an electron is

0.000,000,000,000,000,16 coulomb, (written 1.6×10^{-19})

a flow of one ampere requires that

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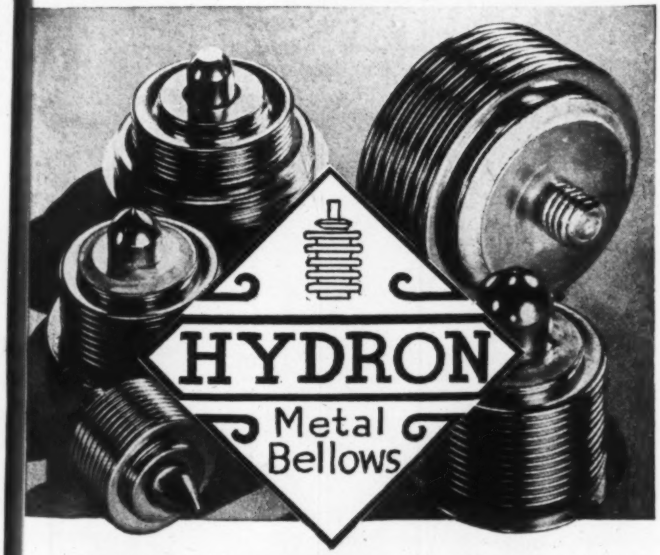

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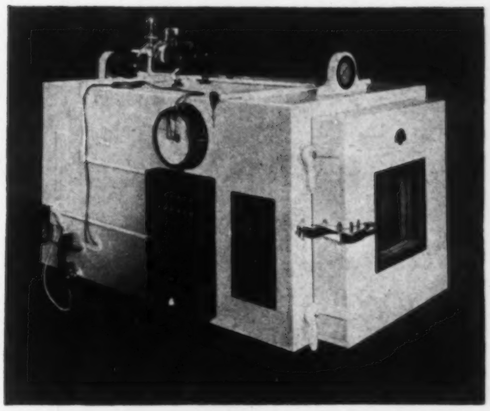

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rents the statement that the electrons move toward the positive terminal may be puzzling in view of the fact that in electrical circuits the current is said to be the flow from positive to negative—just opposite to the action described here. The reason for this contradiction is that the old-established convention of representing the current as flowing from the positive to the negative terminals is wrong. The pioneer electrical experimenters, having no knowledge of the electron and therefore no real understanding of the nature of an electric current, arbitrarily assumed the direction of current to be from positive to negative. As now disclosed by the electron theory, they chose wrongly but the convention persists to this day. In view of present knowledge this convention should be abandoned since it is extremely confusing when dealing with electron tube circuits.

(To be Continued)

Newest Developments in Glass Gages

(Concluded from Page 256)

It is entirely possible to grind centers in the ends of plugs, using a tungsten carbide drill and lapping with a center lapping stick, such as a Norton 60 Q ½ × 2; the blanks will be supplied by glass makers with the centers ground in. The question has been asked many times, whether the molded male centers could be supplied on the blank: this is impractical to do in glass molding procedure.

It is not amiss to point out that glass gages are part of the Ordnance gage program. Early in August 1940, approximately one year and three months before Pearl Harbor, it became evident that the peace-time capacity of the gage industry, which is normally about 3½ to 4 million dollars, was insufficient to meet the visualized load of the projected munitions program, taking into consideration Ordnance, Air Corps and Navy requirements.

> From *The History of the United States Army* by Colonel William A. Ganoe (page 512): ". . . The next year [1938] opened propitiously. The President with his usual foresight sent a message to Congress requesting . . . six millions for manufacture of gages, dies and aids to manufacture of arms and munitions."

From surveys made in September 1940, the first general gage expansion program was initiated and approved by President Roosevelt on October 15, 1940, to the extent of four million dollars for increased gage making facilities. This has been followed by four other expansion programs, the total resulting in the expansion of over 100 gage making plants at a cost of approximately twenty million dollars. It is estimated that these facility expansions, with other normal expansions, will have increased the gage making capacity of the country from four million dollars in 1940 to approximately 125 millions at present. In short, the Ordnance Department has been providing new sources of supply as fast as the demand presented itself.

This balance of supply and demand has been accomplished by studying production programs in advance and increasing gage facilities far enough ahead of the programs to meet the objective. A definite policy of design, distribution, surveillance and procurement was set up before this war and with the coöperation of industry, the Ordnance Department has been able to carry out its gage program objective.

The Ordnance Department has developed a gaging policy which many agree is superior to most other policies because it recognizes the vital importance of wear allowance and combines wear allowance with gage makers' tolerances, both allocated entirely within the work tolerance zone. This allocation is graphically and dimensionally described on an Ordnance chart which appeared in *Instruments*, May 1942 issue, page 174; also in *Iron Age*, September 3, 1942 issue.

Nineteen Ordnance gage laboratories were established at manufacturing arsenals and in ordnance procurement dis-

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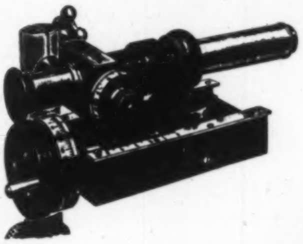
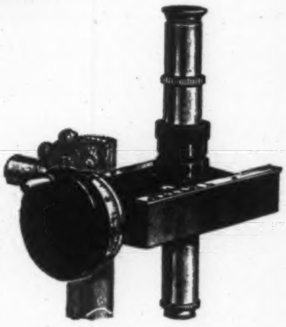


vertical measurements



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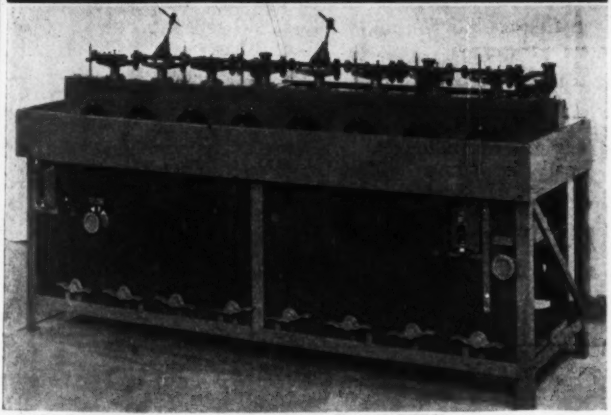

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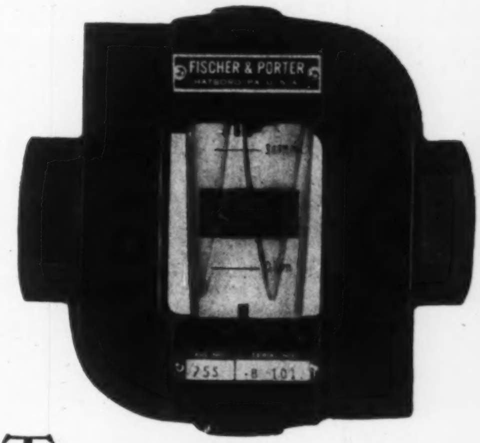

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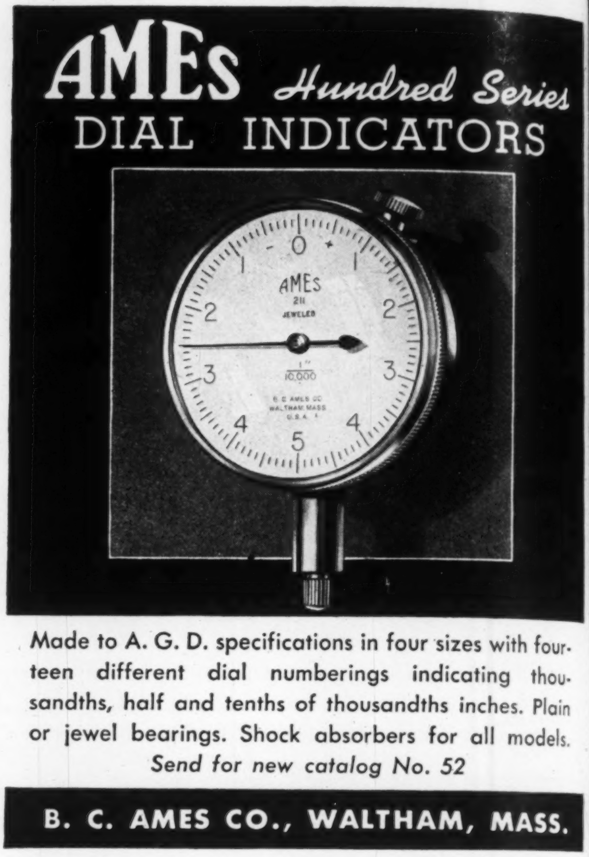
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tricts before this emergency. Those in the districts were located in universities for the purpose of training personnel in this highly specialized work. The foresight of the Ordnance Department in equipping these laboratories in the years prior to the emergency can be visualized when you consider the serious bottleneck which developed shortly after the beginning of this war in the supply of precision measuring equipment, due to the restriction of foreign sources of supply and the longer period required to manufacture this type of equipment.

The district laboratories are responsible for constant gage surveillance to detect worn or damaged gages being used by ordnance inspectors.

The Ordnance Department is constantly striving to improve gaging methods, particularly with the view of obtaining faster inspection. During this emergency many new types of gages have been developed, including multiple-purpose gages employing electrical means for amplification, pneumatic gages for measuring gun bores, special dial indicators for the same purpose and optical projectors for measuring irregular parts.

In concluding this talk, may I say that the Ordnance Department is greatly indebted to you gentlemen in industry for your fine coöperation, without which it would have been impossible for us to meet the objective of this enormous program.

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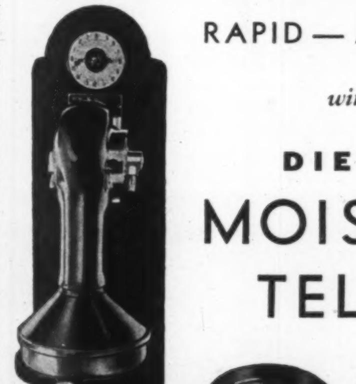

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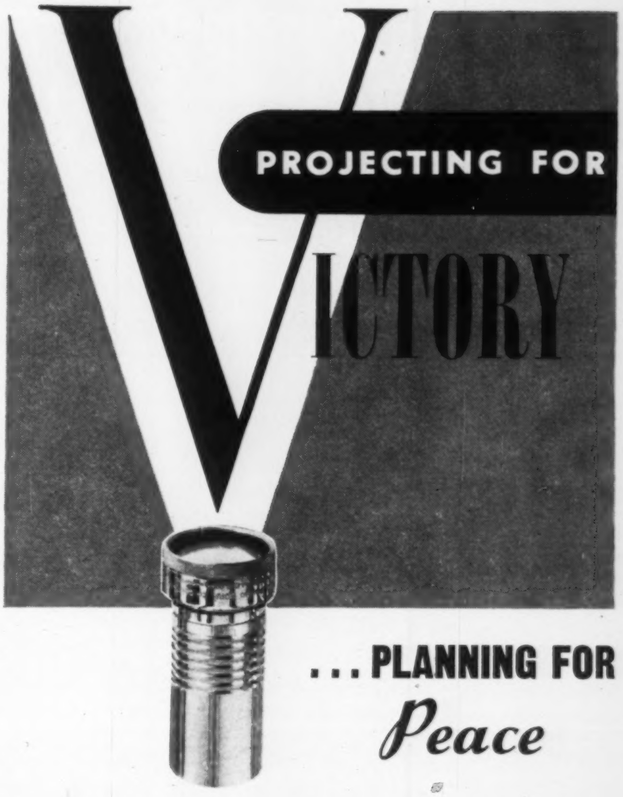

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Control Systems Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-14

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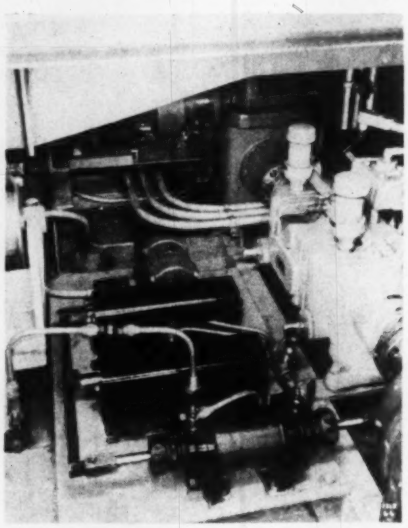
BAILEY METER COMPANY LTD., MONTREAL

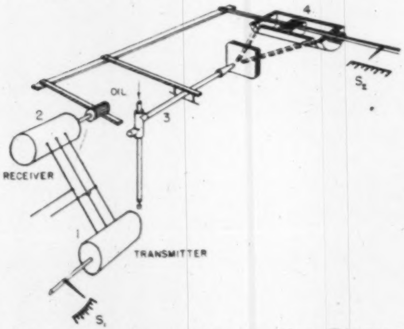
The Month's NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

Remote Electro-hydraulic Transmitter

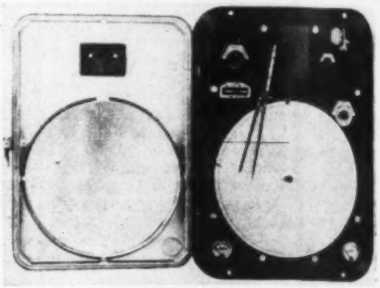
New remote control device combines jet pipe principle with Selsyn telemetering system. Selsyn movement need merely operate the sensitive jet pipe which is practically frictionless and thus transmit the original indication through a hydraulic system with sufficient power to operate heavy dampers, butterfly valves or any other equipment requiring accurate remote operation. Diagram illustrates how movement of Selsyn transmitter (1) is transmitted to receiver (2) which in turn alters position of jet pipe (3), causing a greater hydraulic pressure to result on either side of piston (4). Piston movement is always proportional to the amount of the original Selsyn motor movement. Cylinder can be used to produce a proportional stroke, force or rate of turn proportional to the displacement of transmitter. Factor of power, force or amplification is said to be practically unlimited and accuracy of 0.2% is obtained; greater accuracies can be provided when required. Photograph illustrates application in which the speed of a hydraulically-driven worm gear may be adjusted remotely.—*Askania Regulator Co., 1603 S. Michigan Ave., Chicago, Ill.*





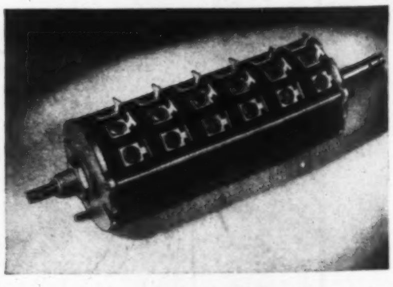
Air-operated Controller

New air-operated automatic control instrument known as "Convertible Free-Vane Controller" is for automatically controlling temperature (up to 3600°F.) flow, liquid level, pressure, draft humidity, pH value, and time program. It operates on the same basic "Free-Vane" principle as that used in maker's previous models but design refinements have been incorporated which simplify instrument, make it more convenient to service and enable user to convert from one type of control system to another. "Convertible Air-Operated Controller" is offered in the following types: "Monoset" (on and off), "Ampliset" (throttling), Preset, Reset, and "Magniset." Adjustments for fitting controller to requirements of process are located on dial board above chart.—*The Bristol Co., Waterbury, Conn.*



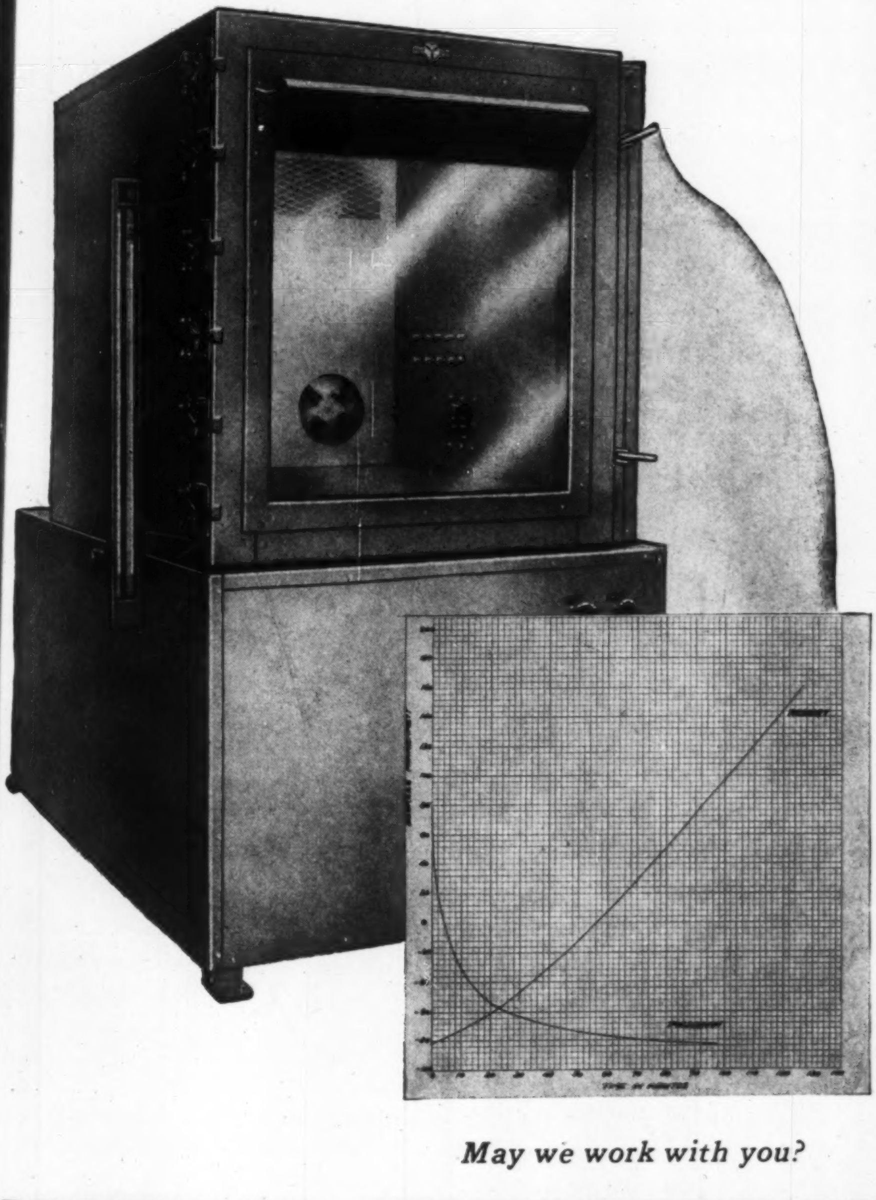
Tandem Controls

A plurality of circuits—up to two dozen if desired—can be controlled by single shaft of "42 Series Control" said to provide maximum rigidity as well as positive rotation of all units without backlash. New design of case for each unit permits nesting and locking all units into a compact stack. Metal end disks and tie rods hold cases together rigidly. Single shaft passes through and locks with each rotor in the stack. Individual units can be of any standard resistance, taper, taps and hop-offs to meet individual circuit requirements. New controls are necessarily made on special order only, since the number of sections and the values vary from one application to another. Units with as many as 20 sections are being produced for critical applications.—*Clarostat Mfg. Co., Inc., 235-7 N. 6th St., Brooklyn, N. Y.*



EXPERTS . . . REFUSE TO BE STUMPED

When a possibility seems an improbability, call in a MOBILE engineer. Over the wide range of requirements for high altitude test and calibration chambers, our men have overcome many of the difficulties which gave instrument manufacturers a headache. Unusual specifications have been successfully met, production test times substantially lowered, greater efficiency effected. All MOBILE units incorporate positive means of refrigeration and control, with an indicating recording controller. Wherever standard models are not suitable, we will build to individual needs.



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HIGH ALTITUDE DEVELOPMENT CHAMBERS

Temperature: −125°F to +180°F, accuracy ±2°F of setting.
Vacuum: to .15"Hg absolute
Time: complete cycle within 90 minutes.
Size: minimum of 12" x 12" x 12" to any greater capacity.
Humidity: 20% to 95% R. H. manual or automatic control.

☆

COLD CHAMBERS

Specifications are identical with those listed above for altitude chambers, except that cold chambers have no vacuum provision.

☆

HOT AND COLD BATH CALIBRATION STANDS

Temperature: −85°F to +600°F.
Control: constant temperature control ±1°F.
Size: 1 pint to 50 gallons; also available with multiple vat units.
Automatic mechanical refrigeration (no dry ice).

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FLIGHT CHAMBERS

Temperature: to −100°F. or without refrigeration.
Vacuum: to 80,000 ft. with automatic control of temperature compared to pressure for dive and climb similitude.
Size: 6' x 4' x 4' to as large as 10' x10' x 50'.
Humidity: manual or automatic control in range between 20% and 95% R.H.

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- Special Recording Pyrometers
- Manometers and Altimeters
- Vertical Speed Indicators
- Oximeters
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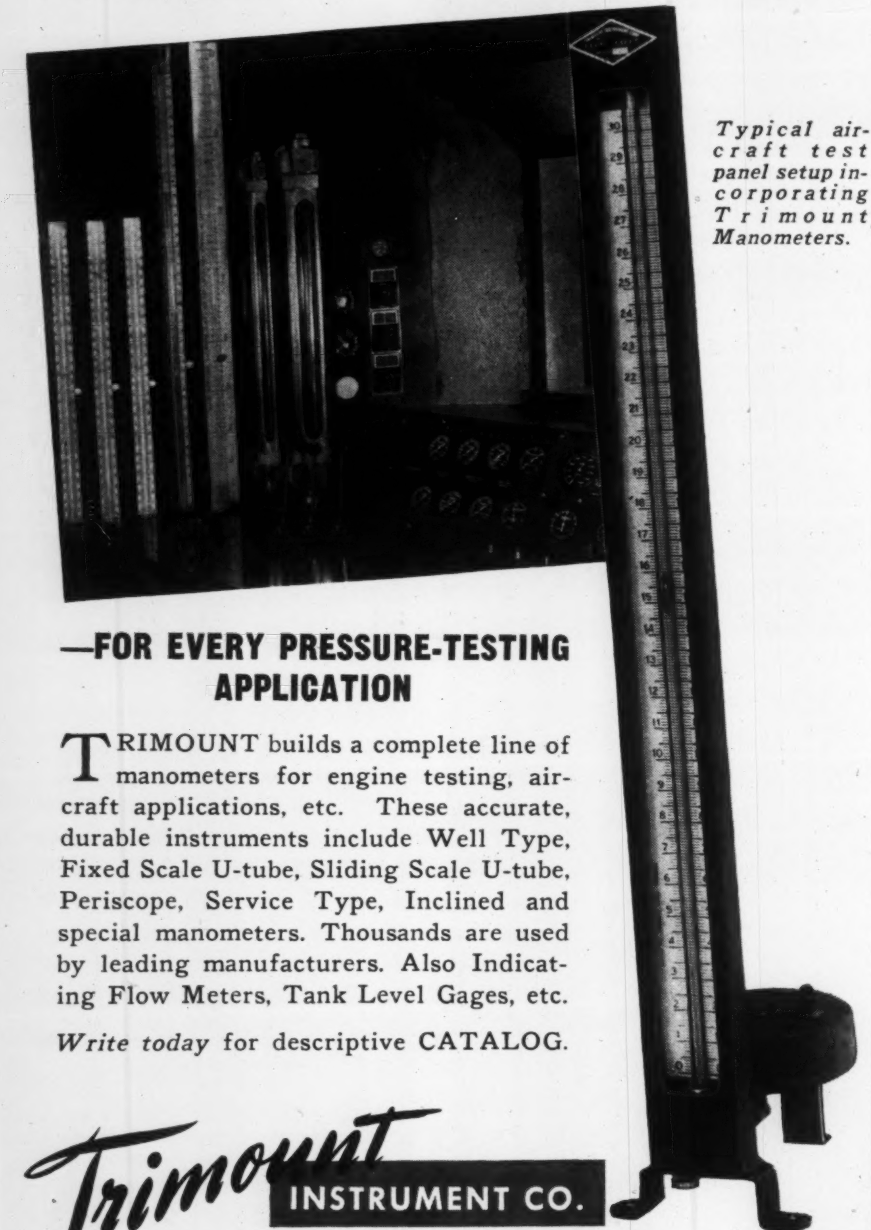

Typical aircraft test panel setup incorporating Trimount Manometers.

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Rotary Drive Rheostats for Switchboard Mounting.
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Vertically Mounted Table Rheostats.
Adjustable Resistors.

PROMPT DELIVERY

Instrument Lathe

New "Aeropoint Victory Model" precision watchmaker's type No. 2 collet lathe embodies a number of features which make it exceptionally suitable for use in shops, factories and instrument organizations, and particularly for field repair applications. The lathe head or spindle, by means of an eccentric and raising block clamps to its bed so that it may be removed and fitted to any standard watchmaker's lathe bed or it can be placed in a milling or vench vise for various operations such as slotting, sawing, filing, etc. (see Fig. 2). This new idea for the head stock spindle permits a wide variety of applications; has collet capacity for standard watchmaker's No. 2 collet chucks up to a capacity of 3/16" through the spindle body. Head stock spindle construction is similar to that of the usual watchmaker's lathe head with tapered adjustable bearings, hardened ground preci-

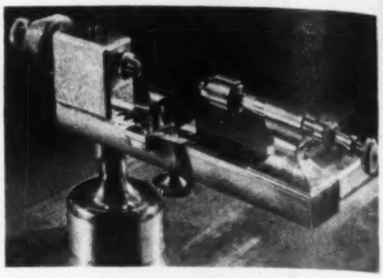


Fig. 1

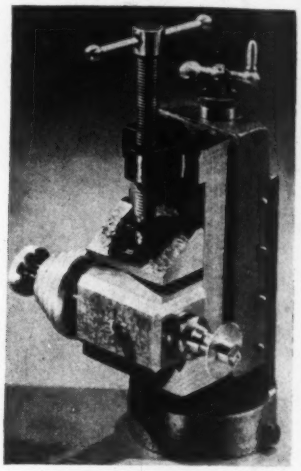


Fig. 2

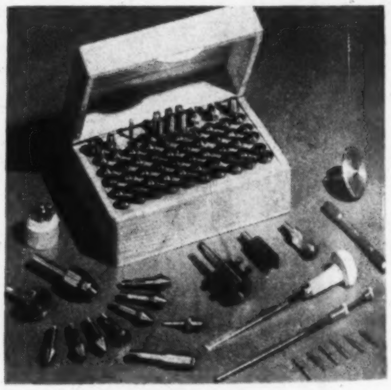


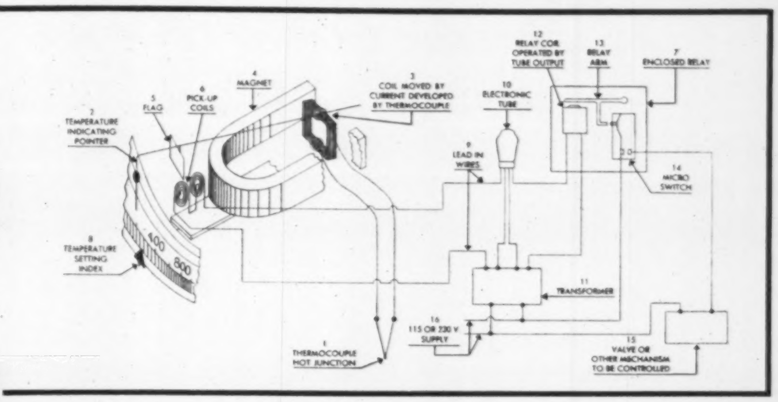
Fig. 3

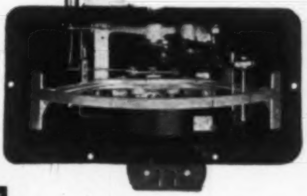
(Continued on Page 310)

Here's How

Wheelco's *"Electronic Principle"*

GIVES CLOSER TEMPERATURE CONTROL...


12
RELAY COIL OPERATED BY TUBE OUTPUT
13
RELAY ARM
7
ENCLOSED RELAY
4
MAGNET
3
COIL MOVED BY CURRENT DEVELOPED BY THERMOCOUPLE
10
ELECTRONIC TUBE
5
FLAG
6
PICK-UP COILS
2
TEMPERATURE INDICATING POINTER
9
LEAD IN WIRES
14
MICRO SWITCH
8
TEMPERATURE SETTING INDEX
400
800
11
TRANSFORMER
16
115 OR 230 V. SUPPLY
1
THERMOCOUPLE HOT JUNCTION
15
VALVE OR OTHER MECHANISM TO BE CONTROLLED



The diagram above shows how Wheelco's "Electronic Principle" Control has been combined with millivoltmeter to provide closer control than is possible with any mechanical type temperature controller.

Temperature change at thermocouple hot junction (1) causes coil (3), carrying temperature indicating pointer (2), to move. When control point, determined by temperature setting index (8), is reached by indicating pointer the flag (5) is between the pick-up coils (6). The change in the inductance of the coils, caused by passing the flag between them, effects a variation in the current input to electronic tube (10) which is reflected in a variation of the tube output. Tube output is used to operate relay coil (12) which pulls down or releases relay arm (13) which in turn, opens or closes micro-switch (14) to establish control of valve or other mechanism (15).

WHEELCO
CAPACITROL

There is no interlocking of any kind between the measuring and control sections. Each is entirely independent in its action. Not only does **closer, faster control** result from this arrangement, but temperature measurement is also more accurate as the measuring system is not retarded or effected in any way by the control operation.

"Electronic Principle" Controllers include a wide range of temperature controllers and special controllers.

Complete information available on request — write today.

Wheelco Instruments Co.
833 W. Harrison Street Chicago, Illinois

Originator of "Electronic Principle" Temperature Controls

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These engineers can help you quickly — at no cost or obligation

If you want to cut your degreasing costs and speed up your metal-cleaning work—if you have a difficult metal-cleaning job that's giving you trouble—get in touch with us *at once!* There is a lot more to solving a degreasing problem than just buying some new degreasing equipment. Our engineers travel from coast to coast working on every possible type of metal-cleaning operation. They have licked some problems that were called impossible. They are *specialists in degreasing* with many years of experience in that field. They will tackle any job—without a penny of cost or obligation to you—*and we mean just that!* Write *today* telling us what your problem is—and you will get quick action!

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A.M. PICK-UP

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This motor was delayed

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sion spindle, etc. In addition, bearings are sealed against outside abrasive dirt and grit. New Victory Model Lathe is available with various accessories, including complete set of collet chucks numbering from one through eighty, various cement brassies, pot collets, wheel chucks, standard drill chucks, jumbo chucks, jewel chucks, extension chucks, etc. (see Fig. 3).—*The Aeropoint Co., 600 South Michigan Ave., Chicago, Ill.*

Cathode-ray Oscilloscope

New "Model 553" 3″ cathode-ray oscilloscope is said to fill the need for an extended frequency 3″ oscilloscope with greater sensitivity. Its compactness, limited weight and construction make it a portable field instrument. Power consumption is 50 watts, low enough for field work. All controls and terminals are located on front panel. Switching arrangement permits applying input either directly to deflection plates or to input of the amplifier. Position and stable locking of image can be obtained with either the vertical signal or any external signal. High gain amplifiers use television tubes for maximum sensitivity. Built-in sweep has the greatest range (15 to 22,000 c.p.s.) consistent with good linearity. *Other Specifications*—Input impedance: through either amplifier 0.5 Megohm 20 mmfd.; without amplifier 2.2 Megohm 40 mmfd. Deflection sensitivity: through either amplifier (max. gain) 0.6 r.m.s. per inch, without amplifier 35 r.m.s. per inch. Amplifier frequency response ±3db, 20-100,000 cycles. Intensity control controls bias on grid of cathode-ray tube, which in turn determines electron emission from the cathode, thus controlling size of spot. Focus control regulates potential between first and second anodes, with constant potential on second anode. Vertical amplifier control is a 500,000-ohm voltage divider in input circuit of vertical amplifier; its position determines what fraction of the signal is impressed on grid of amplifier, thereby controlling apparent gain of amplifier. Horizontal amplifier control, likewise, determines what fraction of the "time axis" voltage is amplified. Coarse frequency control is a five-position rotary switch which selects the capacitor value for the "time axis" generator, thereby controlling the generator frequency. Fine frequency control is a 2-megohm rheostat in series with the coarse frequency capacitor; permits a gradual change of frequency within the limits of the coarse frequency selector. Sync. control is a 15,000-ohm voltage divider in the grid input of the linear time axis generator; its position determines fraction of vertical signal impressed on the "time axis" generator. It serves as a means to lock the image. Beam controls are 250,000-ohm resistors; their positions vary the potentials between the deflecting plates, thereby allowing spot to be moved to any position on screen. Vertical amplifier switch connects the "vertical input" binding posts either directly to the deflecting plates of the cathode-ray tube, or to the input of

(Continued on Page 312)

THE PERKIN-ELMER CORPORATION

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In the field of science The Perkin-Elmer Corporation name is one of utmost familiarity. In its work for astronomical observatories and scientific laboratories, it has been able to achieve accuracy of optical systems never previously achieved.

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To help win the war Perkin-Elmer cheerfully and wholeheartedly answered the nation's call to drop everything else and go to work for the Armed Forces. The Perkin-Elmer Corporation was one of only three companies in the field of precision optics to win the Navy E for excellence and ingenuity in production of precision optics. It was later replaced with the joint Army-Navy E award with star.

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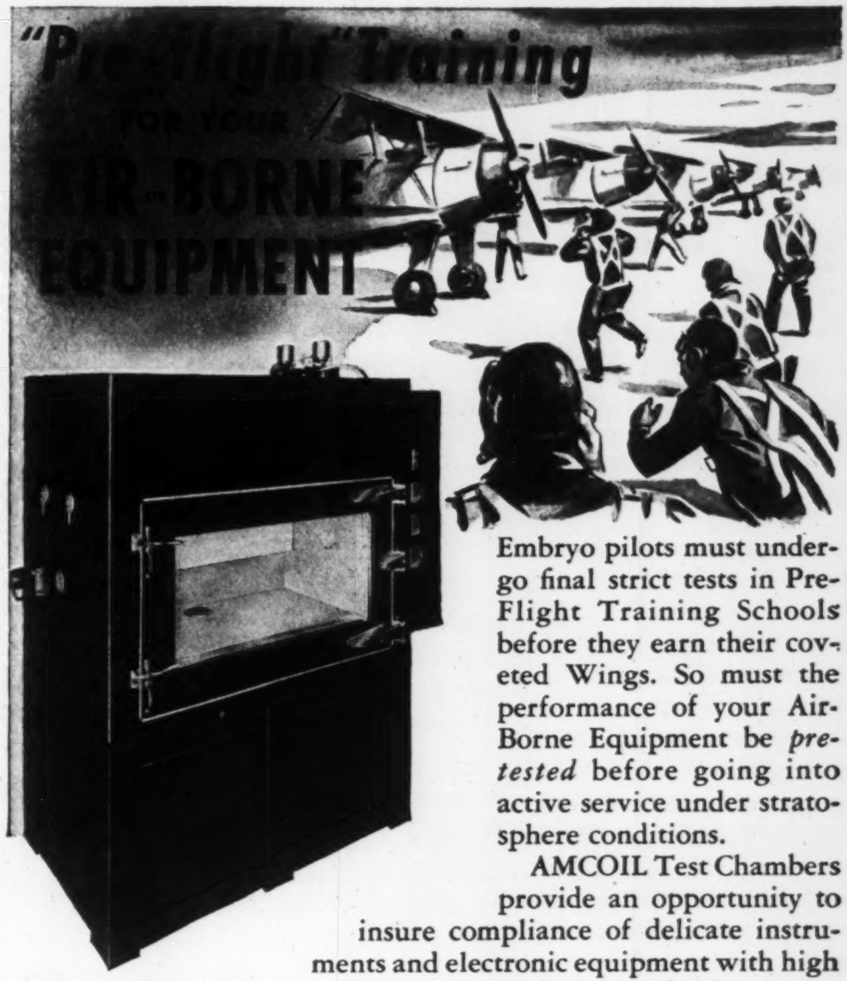

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MODEL RTC-1 Mechanical Refrigeration. Temperature Range, −55° C. to +70° C. Usable Interior, 28.7 cu. ft.

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AMCOIL Test Chambers provide an opportunity to insure compliance of delicate instruments and electronic equipment with high and low temperature specifications prior to their use. AMCOIL completely automatic temperature test chambers combine mechanical refrigeration and electric heating, thermostatically controlling low and high temperature ranges from −70° to +70° C. (−95° F. to +160° F.). They have an exceptionally fast rate of pull down, (ambient to minus 50° C. in less than one hour, without productive load). Test conditions are easily controlled from a front panel board. Door has five thicknesses of glass, hermetically sealed and protected against moisture seepage, thus assuring clear visibility always.

Cubical contents of AMCOIL chambers range in size from 7 cu. ft. to 28.7 cu. ft. and are available with either mechanical or dry ice refrigeration; also special chambers for altitude and humidity testing.

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Tests

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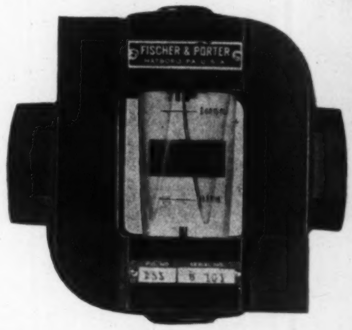
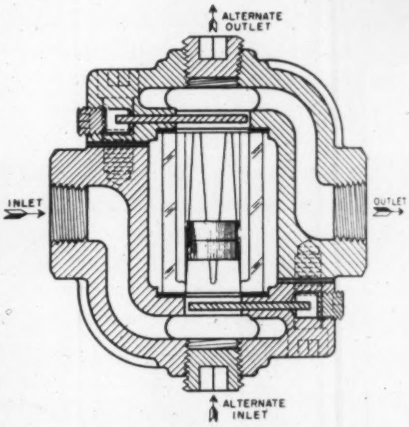
the vertical amplifier. Horizontal amplifier switch connects horizontal amplifier either to internal time axis generator or to external sweep. It furthermore permits internal or external synchronization. In its most clockwise position, it connects the "horizontal input" binding posts directly to the deflecting plates.—*Radio City Products Co., Inc., 127 W. 26th St., New York City.*

Flow Indicator

New "Rota-Sight" is for flow indication in any application where an approximation of flow rate is an operating aid and necessity. It shows when a liquid or gas is passing through a line and has an indicating float which moves up and down in a pyrex tube in direct proportion to flow. Flow-measuring principle, however, is different from that of Rotameter, as response is obtained by the uniquely designed pyrex tube's triangular V-ported flutes, constituting a variable area meter giving a wide range over a short scale length. "Rota-Sight" is sensitive to low flows and informs operator the second the flow starts. Float is readily visible even through opaque fluids. Metering tube is 3″ overall and fittings are hollow so that flow may pass through them. Therefore "Rota-Sight" may be connected for flow passage in several ways. Tube may be engraved for checking one flow rate or for holding flow between a high and a low rate; or an arbitrary reference scale may be provided. To give visible or audible alarm against dangerously low or high flows, instrument may be equipped with a magnetic float extension which trips a magnetic switch. High and low alarm positions are adjustable over entire flow range.—*Fischer & Porter Co., 924 County Line Road, Hatboro, Pa.*





Precision Coil-turn Counter

New precision coil-turn counter for laboratory or factory use employs same circuit as its predecessor but is more compact in design and incorporates a magnetizing

(Continued on Page 314)

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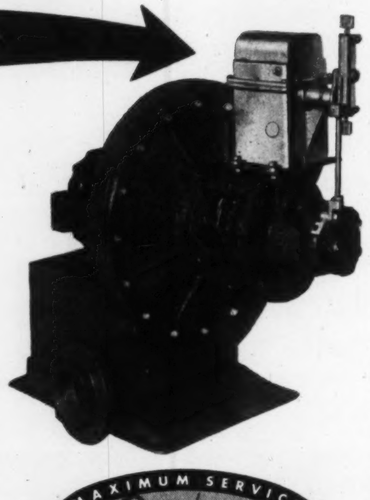

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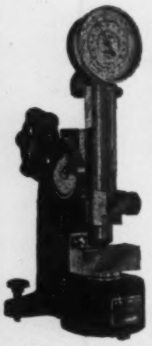

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Available in a number of double-range combinations, such as 1 volt and .1 volt, 100 MV and 10 MV, also in pH ranges. Guaranteed accuracy .1%. *An outstanding value.*

Described in Bulletin 270 which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

We also make galvanometers, colorimeters, permeameters, Wheatstone and Kelvin Bridges, resistance standards, coil testers, acronographs.

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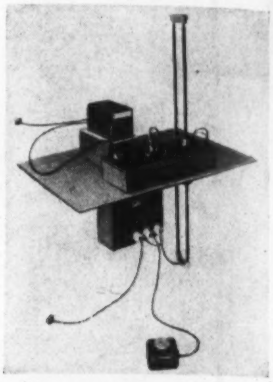
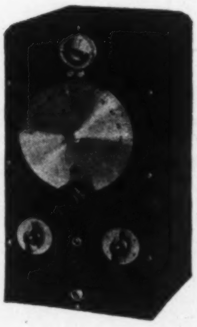
current control box which greatly simplifie installation. New counter is capable checking or determining effective turns coils, from 1 to 11,110 turns, at a rate 80 to 100 coils of like specifications p hour. New coil-turn counter comprises magnetizing current control box, a portab light-beam galvanometer, two yoked te rods, a galvanometer control panel, and foot-operated switch—all conveniently as sembled for operation on a table or bench Operation: Coil to be tested is placed ove test rod and connected to test clips. Dial on galvanometer control panel are set



number of turns the coil should have; foot switch is pressed: If galvanometer dial shows a deflection, dial readings are increased or decreased until deflection is zero. Dial reading is then the number of turns. When probable number of turns in a coil i not known, a trial reading is taken and dial is adjusted until galvanometer reading is zero. Instead of being mounted separately as with previous counter, reference coils of new counter are enclosed in galvanometer control case while test rods are mounted on case. Better protection for reference coils and more compactness result. In addition, this arrangement allows production coil to rest close to reference coil with which it is compared. Use of a magnetizing current control box simplifies installation since no additional wiring is required: simply plug in connecting cord of box. Magnetizing circuit is designed to operate from a 120-volt d-c. supply when used with a resistor furnished as part of control box, or from a 20-volt storage battery without a resistor. Accuracy of counter is one turn in a thousand for coils having air cores at least ⅝" diameter, an outside diameter of 8" and less, a coil build-up to 2⅝" and up to 6" in height. Accuracy is not as high for coils outside these limits.—*Special Products Section, General Electric Co., Schenectady, N. Y.*

Precision Frequency Meter for Megacycle Ranges

New "Type S-2" frequency meter has an accuracy of better than 0.005%, operates on a.c. or d.c., is designed for checking frequencies in any five bands (25 to 500 kc. wide depending on location in spectrum) from 1.5 to 60 Mc. A 100-kc. crystal is used as a secondary standard. Its frequency may be checked readily against National Bureau of Standards' Station WWV or any reliable broadcast station operating on a multiple of 100 kc. Extremely stable electron-coupled oscillators are used to cover a band of fre-



(*Continued on Page 316*)

PERMANENT MAGNETS

They provide SUBSTANTIAL SAVINGS in ENERGIZING COSTS over Electro-Magnets

WHEN properly designed for each application, the permanent magnet, as made today of today's improved magnet steels, offers real opportunities for saving the user substantial amounts in power costs.

For example, the recently perfected steels, ALNICO and NIPERMAG with their powerful energy contents, permit the use of much smaller permanent magnets than hitherto has been possible. Yet they can do the work of electro-magnets without the latter's attendant power costs.

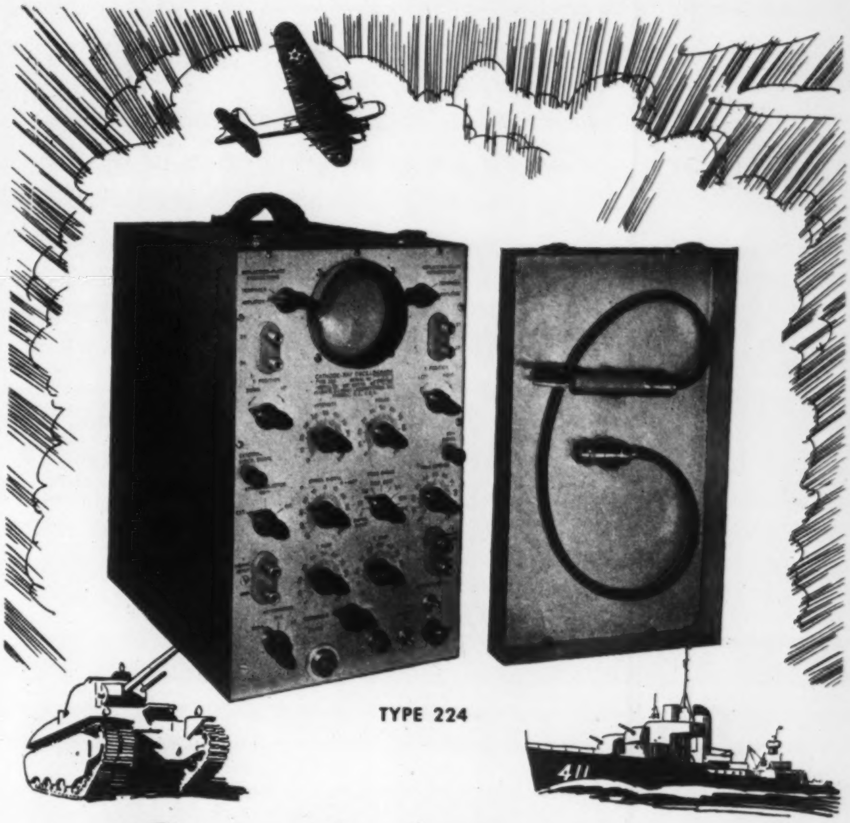
Cinaudagraph Engineers have made permanent magnets their specialty for many years. They will be glad to help you design the best type of magnet for your equipment and then produce it in any quantity needed for your production program.

ARMY E NAVY

F C-2

CINAUDAGRAPH CORPORATION

STAMFORD, CONNECTICUT



TYPE 224

Another DuMont War Baby

FREQUENCY RESPONSE TO TWO MILLION CYCLES!

Widest variety of signal input connections. Signals can be connected directly to deflection plates of 3" cathode-ray tube when frequencies are above useful limits of amplifiers.

★

Y-axis or vertical deflection response uniform from 20 c.p.s. to 100 kilocycles. Both with distortionless input attenuators and gain controls.

★

Y-axis amplifier has input connection for test prod and shielded cable reducing input capacitance and eliminating usual stray pickup.

★

All high-voltage electrolytic capacitors are eliminated from circuit.

★

14⅛" h.; 8⅜" w.; 15⅛" d.; 49 lbs.

★ Out of the flaming crucible of war which tries equipment as well as men's souls, comes this new DuMont Type 224 Oscillograph.

First and foremost, its wide band Y-axis amplifier permits study of signals of frequencies far beyond the range of standard oscillographs. It has a comparably faithful square and sinusoidal wave response. Second, it is a more versatile oscillograph, providing extreme variety in the application of signal to the cathode-ray tube. Third, it is housed for severe service out in the field as well as in plant or laboratory. Protective, removable cover safeguards panel and controls when not in use, especially in transit.

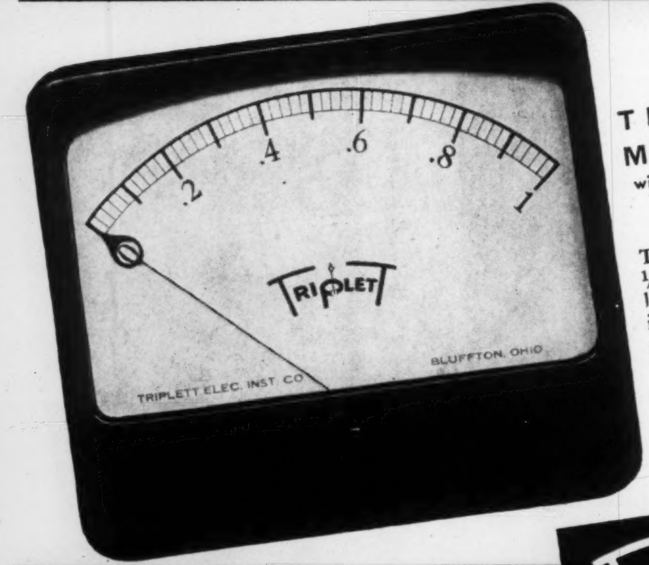
These and other attractive features make this war baby outstanding among oscillographs.

Write for Literature

DUMONT

ALLEN B. DU MONT LABORATORIES, Inc.
Passaic • New Jersey
Cable Address: Wespexlin, New York

TRIPLETT
Combat Line INSTRUMENTS



TRIPLETT
MODEL 626
with long 5.60" scale

★

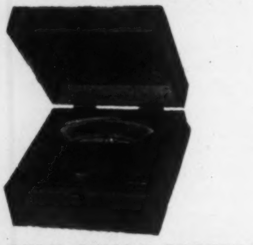
This illustration is ½ actual size. Note long scale and minimum panel space required.

TRIPLETT

A WORD ABOUT DELIVERIES
Naturally deliveries are subject to necessary priority regulations. We urge prompt filing of orders for delivery as expeditiously as may be consistent with America's War effort.

TRIPLETT ELECTRICAL INSTRUMENT CO. . . . . . BLUFFTON, OHIO

TEST MAGNETIC PROPERTIES OF YOUR STEELS



THE ONLY SINGLE BUTTON ELECTRICAL RETURN FLUXMETER
SIMPLEST AND MOST EFFICIENT
Bulletin 504
THREE DIFFERENT STYLES

Portable Standard with single electrical zero return.

Switchboard Type with above zero feature located on flexible lead for bench operation.

Two Button Pointer Shift in place of our patented standard zero return at a lesser cost.

Acknowledged leaders in development of high sensitivity meters

RAWSON ELECTRICAL INSTRUMENT COMPANY
110 POTTER ST. CAMBRIDGE, MASS.
Branch: 15 East 26th St., New York City
Representative: E. N. Webber
1313 West Randolph Street, Chicago, Ill.

ZEISS HEADBAND MAGNIFIER
Leaves hands free

Use of both eyes reveals true depth of details. Magnification of 2¼x. Free working distance, 8" to 10", permitting unhindered use of hands. By just lifting your head, your eyes are free for any other activity. Eyeglasses may be worn while using. Highest optical quality. Black Tenite plastic—practically unbreakable.

ZEISS Aplanatic Folding Magnifiers

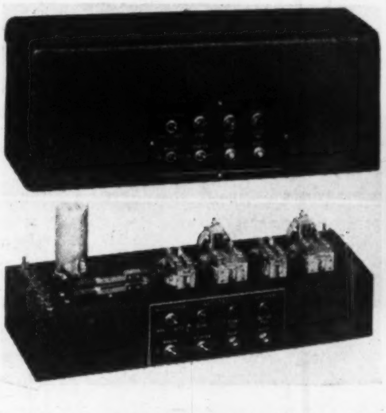
In bakelite mounts. Wide field, high luminosity and excellent definition for close-up examination. Two types: A 6-power magnifier consisting of an aplanatic lens system . . . A 9-power magnifier which has the 6-power system and a 3-power lens. Both may be used singly as 6x or 3x magnifier or in combination, resulting in a 9-power magnification.

Write for literature
CARL ZEISS, Inc., Dept. HN-49-5
485 FIFTH AVE., New York

quencies from 25 to 500 kc. wide. The required frequencies are included in these narrow bands. At least two points on any band may be checked against the 100 kc. crystal oscillator. Slight adjustments of the variable oscillator by means of a front panel control are made when necessary. To facilitate zero beat adjustments, a tuning eye is employed. A phone jack is provided so that zero beat may be indicated aurally as well as visually. Tuning eye is employed both in checking the variable oscillator against the 100-kc. crystal and the transmitter against the variable oscillator. It may be used also to check transmitter frequency deviation. Checks on the transmitter frequency may be made rapidly (average time less than a minute). Accuracy: There are 200 divisions on the main 5½" tuning dial. Reading to ½ division is entirely feasible. At 1500 kc. this provides a reading accuracy of 0.004% with a band spread of 25 kc. Same accuracy at 30 Mc. is obtained with a band spread of 500 kc. The calibration curve is drawn in the laboratory by means of a frequency standard whose accuracy is better than 5 parts in 5 million and which allows check points every 10 kc. Line voltage changes of 10% have a negligible effect; temperature error for change of 10°F., 0.002%. Time to reach operating temperature, about one hour. Means are provided for changing crystal frequency slightly so that it may be adjusted to 50 parts in 5,000,000 against WWV by zero beat method.—*Browning Laboratories, Inc., Winchester, Mass.*

Automatic Starter for Internal-Combustion Engines

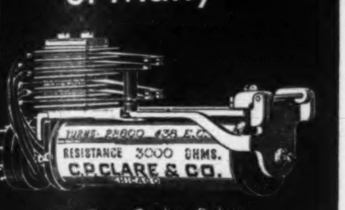
New "Autotrol" has been designed for automatic engine starting and control; for emergency standby and remote-controlled generator sets for automatic operation of



engine-powered equipment. It is said to make engines as adaptable to control as electric motors. Its specific functions are described under seven headings: (1) Ignition—Provides ignition circuit or fuel supply control. (2) Choke—Provides automatic choke during starting and warm-up period. (3) Auxiliary Fuel Supply—Provides power to operate auxiliary fuel pump during starting. (4) Overcranking Protection—Provides five cranking cycles. If unit fails to start after five times, "Autotrol" stops further cranking and lights signal "Start Fail." (5) Engine Safety Controls—Provides for the use of oil pressure failure, water temperature and other safety protective devices. Automatically removes these from the circuit during starting period. If engine is shut down by these cutouts, a signal light indicates "Cutout Fail." (6) Parallel Protection—When engine-driven generators are operated in parallel, provides means of opening magnetic switch on generator in case of engine failure, thus preventing generator from "motoring" on the line. (7) Se-

(Continued on Page 318)

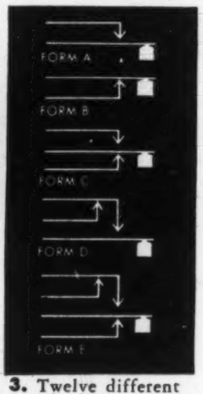
his CLARE Relay
an Take the Place
of Many

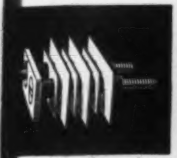


Clare Type C d. c. Relay

This rugged multiple-contact relay ermits innumerable contact arrange- ents. Permits designing to small ze, with a lesser number of relays; nd facilitates maintenance. Adapted r use in electronic control devices nd for sequence control and inter- cking operations. Ideal where un- sual arrangements of relay control e desired. Here are the reasons why:

. Contact springs nploying any of the rms illustrated can be nished.



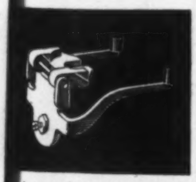


. Spring pile-up in- lators of heat treated kelite which permit unching without acks, have minimum old flow and low oisture absorption ontent. Assembly cked together under ydraulic pressure. ithstands heavy eakdown tests.

3. Twelve different standard or special types and sizes of contacts can be furnished. Contacts are overall-welded to nickel silver springs. Sizes range from .062" silver, rated one ampere, 50 watts, to .1875" tungsten, rated four amperes, 500 watts.

4. Spring bushing in- ulators are Bakelite od made by a patent rocess. Strong, hard, ong wearing. Essential here heavy contact ressures are employed, here vibration exists, r heavy duty service s desired.

5. Armature assembly single or double arm. Has stainless steel shaft, operating in a marine brass yoke. Heel piece, coil core and armature are magnetic metal carefully annealed. Designed for d.c. service.



6. As illustrated, relay has octal base plug mounting for easy service and replacement. Other mountings, and Bakelite or metal cover, can be supplied.

• • •

This relay is an example of Clare "custom-built" design and construction. Clare engineers can "custom build" a relay to meet your specific requirements—one that will reduce your overall relay cost and simplify your design problem. Write for catalog and data book. C. P. Clare and Co., 4719 West Sunnyside Avenue, Chicago.

LARE RELAYS

"CUSTOM-BUILT" Multiple Contact Relays for Electrical, Electronic and Industrial Use

STROMBERG
Automatic TIMERS

for EVERY INDUSTRIAL NEED

STROMBERG
START
CHANGE
SET
BACK
0
5
10
15
20
25
30
35
40
45
50
55

No. 55 Process Timer

Stop waste . . . Substitute mechanical precision for guesswork . . . Save precious material and man hours . . . Improve quality and increase production with reliable, **automatic** Stromberg Timing Instruments.

Ruggedly constructed for heavy service. Sealed to exclude dust and moisture. Not affected by temperature changes. Easily set for any time interval within the dial range. Makes or breaks an electrical contact at the end of each cycle. A glance tells the interval set, the time elapsed and time yet to run. During operation, the time interval cannot be altered. Dial ranges are available to fit any application.

The No. 55 Process Timer runs for the time interval set, makes and holds a contact until it is reset and restarted.

The No. 57 Automatic Repeating Timer makes a contact at the end of the interval set, automatically returns to zero and begins a new cycle—repeating this program until stopped or changed.

Use Stromberg Timers to ring signal bells, light signal lamps, start and stop electric motors, reverse drafts, open and close valves. Thousands are in use today in steel plants, tool industries, rubber processing plants and in baking, preserving, tanning, enameling, plating and heat treating processes.

Write us for complete information. Our engineers will be glad to study your problem and make recommendations without obligation to you.

STROMBERG
1
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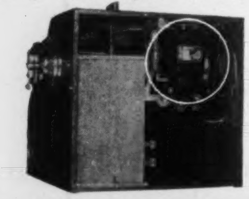
No. 57 Automatic Repeating Timer

STROMBERG TIME CORPORATION
SUBSIDIARY OF GENERAL TIME INSTRUMENTS CORPORATION
109 LAFAYETTE STREET NEW YORK, N. Y.

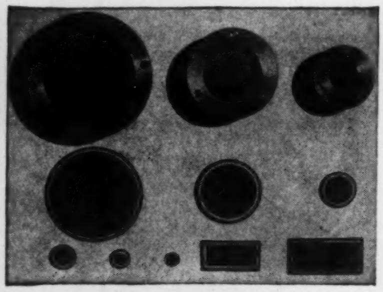
Motors
and reducers
for precision
Instrument Applications



E. H. Sargent Company's "Heyrovsky Polarograph" is operated by a smooth-running Bodine speed reducer motor.

A wide variety of sizes and specifications make it possible for Bodine to supply standard-type motors engineered to each individual application. Quality materials and high standards of workmanship insure the dependable operation that has caused many instrument manufacturers to standardize on Bodine motors. Bodine Electric Co., 2244 W. Ohio St., Chicago, Illinois.

BODINE FRACTIONAL HORSEPOWER MOTORS



PHOTOCELLS
(Barrier-Layer Type)
of highest sensitivity

- Great variety of sizes and shapes
- Unmounted or mounted in various styles of casings
- Full cooperation regarding application and circuits

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Write for literature also on

Colorimeters
Smoke Meters
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Electronic Photometers
Street-Lighting Meters
Continuous-Flow Colorimeters

Today Precision *Must* Be Commonplace

American fighting men on our fighting fronts depend upon production line accuracy . . . for ten-thousandths of an inch variation on the production line can mean the difference between a hit or a miss on the battleline.

The Bausch & Lomb Contour Measuring Projector makes such accuracy possible on the fastest moving production lines, because it takes many vital inspection jobs "off the surface plate" and eliminates the tedious, time-consuming computations of the "sine bar." Inspections for accuracy become routine jobs.

Throwing an accurate, sharply defined shadow image of the object under examination on a translucent screen, the B&L Contour Projector permits exact measurements or comparison with an enlarged template drawing at magnifications great enough for easy and accurate dimensioning.

Here again is a Bausch & Lomb peacetime development that serves America at War. The B&L Contour Measuring Projector is helping speed production of fighting tools for our fighting men.

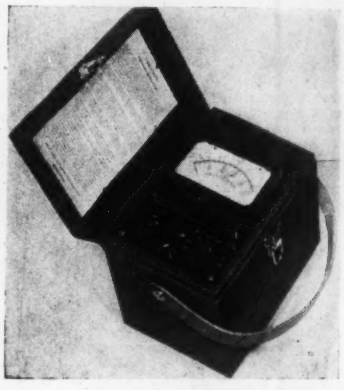
For Bausch & Lomb Instruments essential to Victory—priorities govern delivery schedules.

BAUSCH & LOMB
OPTICAL COMPANY • ESTABLISHED 1853

lective Control—Selective switch provid for both manual and automatic contro "Autotrol" uses a high-torque synchronou motor obtaining a-c. power from the engin battery through a vibrator type converte thus eliminating thermal time relays. Th time cycle remains constant from 60% o battery voltage, thus guarding agains functional failure due to low battery vol age. "Autotrol" is made in four differen styles to accommodate magneto, batter and Diesel ignition engines, together wit several styles of cranking cutoff contro Start and stop may be controlled from variety of devices, such as: Remote manua station, power failure relay, current relay pressure switch, temperature switch, tim switch, electric light load, or radio signa —*Pacific Enterprise Products Co., 2833 E Eleventh St., Los Angeles, Calif.*

Megohmmeter-ohmmeter-voltmeter

New "Model 201 Vibrotest" insulation an resistance tester has ranges of 0-200 meg ohms at 500 volts potential as a megohm meter and 0-2000 ohms as an ohmmeter also voltage ranges of 150-300-600 volts a.c and d.c. Instrument is described as "a American-made crankless megohmmete which through the use of a refined syn chronous vibrator system delivers 500 volt potential at the terminals." One of exclusiv features is a bleed-off resistor which effec tively protects operator from any capacitive charge and shock when disconnecting the leads from a circuit just tested. Possibility of error in readings due to surface leakage is eliminated by a guard circuit on one terminal. Scale is said to be unusually long and exceptionally legible. Indicator has a rugged permanent-magnet moving-coil type of movement. Instrument has substantial metal case with space in metal cover for a pair of 5-foot test leads. Battery life is exceptionally long by reason of low current drain: under normal conditions, 12 to 14 months. *Associated Research, Inc., 231 S. Green St., Chicago, Ill.*



Crystal-controlled Frequency Meters

Four new models of "Telrad" frequency meters are crystal-controlled and, by means of a class "C" harmonic amplifier circuit embodied in the units, accurate frequency carrier signals are provided every 10 kc. and every 100 kc. from 100 cycles to 45 megacycles. A carrier signal is also produced every 1000 kc. from one megacycle to 120 megacycles. A panel-mounted "on-off" switch permits use of a 1000-cycle modulated note. New frequency meters are said to be extremely easy to operate. No cali-

(Continued on Page 320)

ARMY E NAVY
Multiple CONTROLS

★ An entirely new design for tandem controls. New mold provides unit casings that nest and lock together. Metal end-pieces and tie rods insure rigid assembly—even up to 20 units in tandem. Single shaft passes through and locks with rotor of each control.

Each section accurately wound to precise circuit requirements — resistance, taper, taps, hop-off. Interlocking resistance ratios provide any desired voltage or current at given degree of rotation. These Multiple Controls are now in regular production and meeting the most rigid multi-control requirements.

★ Send us that problem . . .

CLAROSTAT *Controls and Resistors*

CLAROSTAT MFG. CO., Inc. - 285-7 N. 6th St., Brooklyn, N. Y.

18"
8"
9"
GOOD & small

HATHAWAY TYPE S-12
OSCILLOGRAPH

An ultra-small, highly portable instrument—designed for uses where these characteristics PLUS excellence of operation are of paramount importance.

***Ideal* for flight testing of airplanes, portable geophysical work or field testing of any kind where extreme portability is desired.**

Only 18″ by 9″ by 8″—yet has 10 channels and records on 6″ paper or film! ● Galvanometers available covering wide range of characteristics; natural frequencies to 10,000 cycles. ● Gear-driven recording, quickly adjustable from ½″ to 20″ per second. ● Simultaneous viewing and recording. ● 'One switch' operation, remote if desired. ● Accurate time-coordinate lines. ● Daylight loading. ● Automatic numbering and record length control, with continuous indication per foot of record used. ● All controls on one panel on top. Write for added facts and prices to . . .

HATHAWAY INSTRUMENT COMPANY
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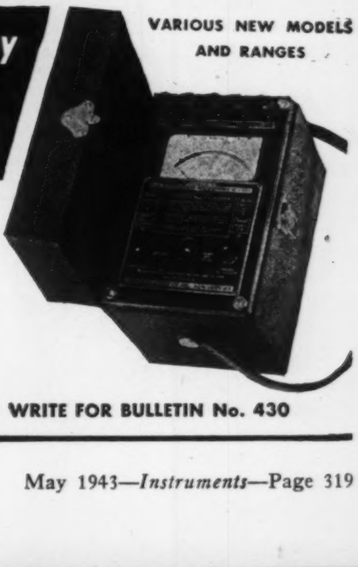
Orders Accepted Now for Early Delivery

Hathaway INSTRUMENTS

Test Insulation the Modern Way with a MODEL B-5 MEGOHMER

VARIOUS NEW MODELS AND RANGES



NEW BATTERY-VIBRATOR TYPE

No more tiresome cranking of a hand-driven generator . . . Entirely self-contained, steady test potential of 500 volts DC, available at the touch of a switch. Direct reading in insulation resistance.

HERMAN H. STICHT CO., INC.
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WRITE FOR BULLETIN No. 430

LUXTRON
BRADLEY PHOTOELECTRIC CELLS
PHOTO ELECTRIC CELLS

NO AMPLIFIERS NEEDED WITH LUXTRON* CELLS

- Prompt, highly efficient conversion of light energy into electrical energy is effected by Luxtron* Photo-Electric Cells.
- Luxtron* cells develop sufficient current to operate instruments and sensitive relays without using auxiliary voltage or current sources . . . and without using amplifiers.

WHICH MEANS LESS BULKY EQUIPMENT

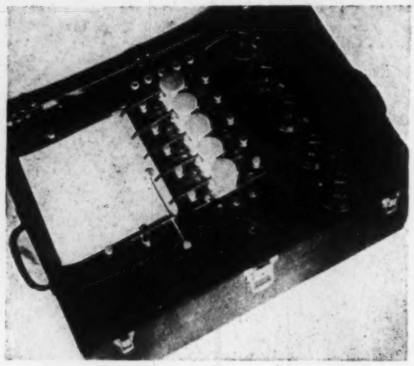
- The advantages of Luxtron* cells are told more fully in illustrated, engineering literature available on request. Similarly available is consultation on special problems and applications.

BRADLEY
PHOTOELECTRIC CELL

This pigtail-contact model is only one of a series of mountings and indicates only one of the complete range of Luxtron* cell shapes and sizes available.

* Reg. U.S. Pat. Off.

BRADLEY
LABORATORIES, INC.
82 MEADOW STREET, NEW HAVEN, CONN.



GARCEAU VELOGRAPH
DIRECT WRITING OSCILLOGRAPH
Quintuplet Model

(Inkless writing on electrically sensitive paper)

Designed for study of vibration in aeroplanes, analysis of pressure in rotating and reciprocating machinery, seismography, oscillographic analysis of welding and other electrical equipment operating on commercial power line frequencies. This direct-writing oscillograph will operate in any position and in the presence of excessive vibration. Particularly adapted to automatic remote control operation. No fragile crystals, permanent magnets nor moving coils.

ELECTRO-MEDICAL LABORATORY, INC.
HOLLISTON, MASSACHUSETTS, U.S.A.

Makers of the Garceau Junior Electroencephalograph

Small Electric Motors
FOR ANY APPLICATION

SpeedWay

For more than 35 years SpeedWay has designed and built small plain and back geared motors to satisfy the thousand varied needs of industry. Today SpeedWay's long experience, mass production methods, and engineering genius are serving the interests of mechanized war promptly and effectively.

If you need small motors—from 1/3000 to 1/3 h.p.—wound for A.C., D.C., or Universal operation—plain or back geared—in quantities of from one to a million—call on SpeedWay.

Send specifications or requirements for recommendations and quotations.

SPEEDWAY MANUFACTURING CO.
1839 S. 52nd Ave. Cicero, Illinois

bration or tuning charts are necessary. Carrier-output is fed into a receiver and carrier frequency of "Telrad" may then be adjusted to zero beat with any receivable primary standard or reference frequency (such as WWV). This zero beat adjustment enables operator to maintain accuracy of the "Telrad" despite temperature variations, so that all harmonic frequencies emitted by the unit will be of the same accuracy. Special models designed for use under adverse conditions are available, equipped with two precision crystals ground to produce exact frequencies of 100 and 1000 kc. and tested for efficient operation at temperatures from -35° to 55° C. and have temperature coefficients of maximum drift of only 2 and 3 cycles per megacycle per degree Centigrade respectively. Models are available for either a.c. or portable battery operation.—*Fred E. Garner Co., 43 East Ohio Street, Chicago, Ill.*

TELRAD
FRED E. GARNER CO. CHICAGO

Millisecond Time-interval Meter

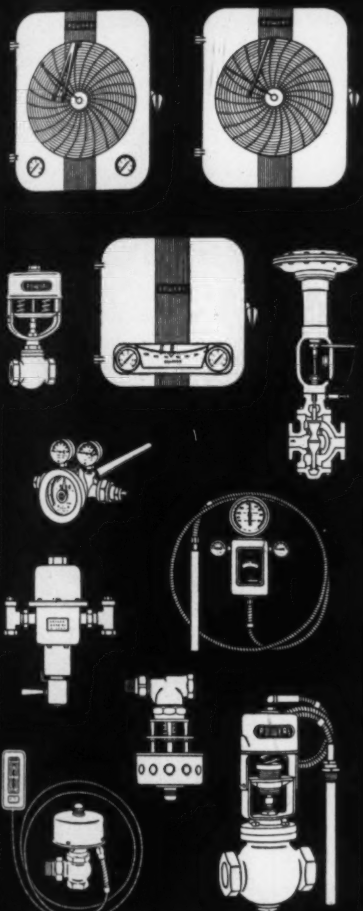
New time-interval meter for extremely short intervals—as low as 100 microseconds—is designed for measuring interval between two events which can be converted into electrical impulses: between closing of two controls; between two impulses to a phototube; between an electrical impulse and a light impulse. Instrument consists of two units, an "electronic" panel and a phototube with its preamplifier stage; has eight ranges selected by means of a tap switch so that any interval between 0.0001 second and 3 seconds can be measured. Direct-reading indicator is calibrated in

(Continued on Page 322)

POWERS

TEMPERATURE and HUMIDITY

CONTROL



When you want accurate and dependable automatic temperature or humidity control for Industrial Processes, Heating or Air Conditioning Systems, call in a Powers engineer. With over 50 years of experience and a very complete line of self-operating and air operated controls we are well equipped to fill your requirements.

Write for Circular 2520

2734 Greenview Ave., Chicago

Offices in 47 Cities—See your phone directory.

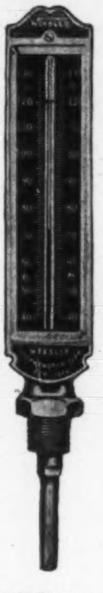
THE

POWERS REGULATOR CO.

WEKSLER

Production or Research Instruments

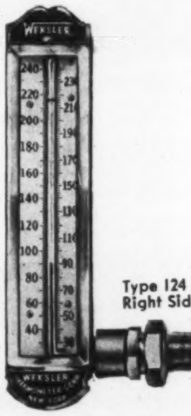
Weksler Thermometers are scientific, precision instruments. Their rugged construction and lasting accuracy will merit your full confidence. Red Reading and Yellow back Mercury tubes are standard in all V shape industrial thermometers. Indicating and recording thermometers are furnished mercury, vapor, or gas actuated. Dial indicating instruments are available in 4½" and 6" phenol condensate cases only, and recording thermometers in 10" chart size. There is a Weksler precision thermometer for every industrial need.



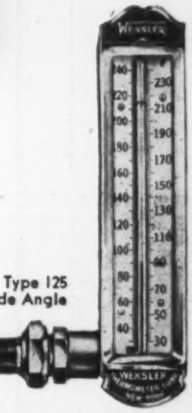
"V" Shaped Bronze Case Industrial

Thermometers and Hydrometers

Dial and Recording Thermometers



Type 124 Right Side Angle



Type 125 Left Side Angle

For information on

Dial and Recording Thermometers, send for Catalog 300 DR

For others, send for Catalog No. 115.

Weksler Thermometer Corporation

52-56 WEST HOUSTON STREET, NEW YORK, N. Y.

Help Wanted—Male

Development engineer. To develop testing devices consisting of electrical and mechanical elements. Should have held similar position. This position offers extremely interesting work to someone who would like to employ their ingenuity and talents in a wide range of endeavor. Job permanent. If now in war industry must secure availability certificate or release from former employer. Vicinity Washington, D. C. Box 75, Instruments Publishing Co., 1117 Wolfendale St., Pittsburgh, Pa.

Help Wanted—Male

Technical sales correspondent by well established laboratory supply house to recommend equipment, prepare quotations and other technical sales correspondence. Successful experience in this line essential. Permanent position. American Instrument Company, Silver Spring, Maryland (suburb Wash., D. C.)

The success of every flying mission

depends on the accuracy and reliability of electrical indicating instruments.

Making them for combat aircraft is a responsibility to which the Boes organization is bringing its closest attention and best skills.

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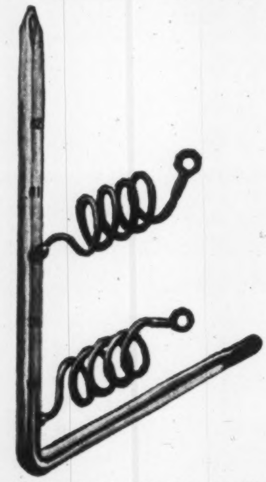
For Extremely Close
Temperature Control

Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

The Philadelphia Thermometer Co.
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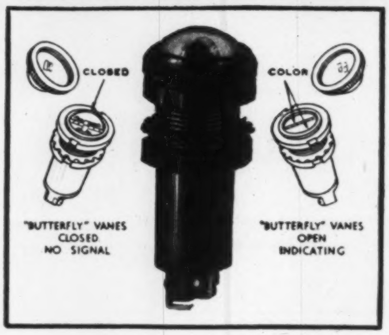
Oldest Thermometer Manufacturer in Philadelphia

NEW! RADIO-ACTIVE SIGNAL INDICATOR

LITTELFUSE Signalette


CLOSED
COLOR
"BUTTERFLY" VANES CLOSED NO SIGNAL
"BUTTERFLY" VANES OPEN INDICATING

No. 1534—Interchangeable with Lamp Assembly AC42B3593

Indicates by reflected light, visible light, "black light" and by fluorescent-radioactive luminescence. Operates by solenoid. When activated, "butterfly" opens showing signal. Red, green, amber and white available. Plastic cap non-shatterable protection. No burnouts. No blur. No dimming. Saves about ½ current.

Wire or write for Signalette bulletin. Ask about samples.

Littelfuses for every instrument purpose. Clips, panels, mountings, etc.

LITTELFUSE Inc.
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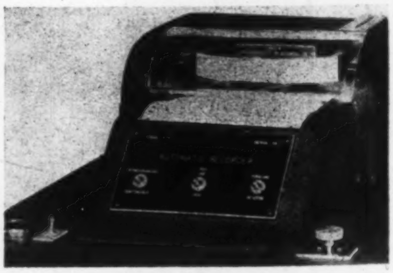
229 ONG ST., EL MONTE, CALIF.

milliseconds. Normal input signals consist of changes of light intensity falling on phototube, or making external electrical contacts. In the former case, light values as low as 0.01 lumen, or approx 1.4 foot-candle, suffice for satisfactory performance. Operating from 115-volt, 60-cycle lighting circuit, instrument is stabilized so that normal line-voltage variations do not affect its accuracy, which is 2% of full-scale value, or one scale division. After measuring, the meter will continue to indicate the time interval with a drift of less than one division per minute. When another reading is required, a push button immediately clears the dial.—*Special Products Section, General Electric Co., Schenectady, N. Y.*

Autographic Recorder for Gear Checkers, etc.

New "Model B" Automatic Checking Recorder is designed for use with maker's Michigan Sine-Line lead and involute checkers and makes permanent chart records of involute tooth forms and leads. Once installed, however, it can be applied to a variety of checking operations: recording variations in dimensions of thread forms, surface checking with parallels and many other checking operations wherein a precise record of dimensions is desired. Only simple changes need be made to provide required electrical connections between measuring unit and recorder. Operation of recorder is based on use of synchronous devices, one located in the recorder and another installed on a bracket in base of gear checker or other type of measuring unit. Any motion imparted to the checker unit is multiplied and duplicated in the recorder through electrical connections between the two units: the same effect as coupling by solid shafting. Two methods of attaching recorder to the measuring device or gear checker are available: Chart drive may either be coupled in synchronism with moving spindle or table of the measuring device, or it may be driven independently by means of a



(Continued on Page 324)

PLASTIC NAME PLATES

SIGNAL CORPS
RACK F
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Engelhard Direct Deflection Indicators have all these features . . . Accurate sensitivity to the most minute voltage variations due to suspension type construction . . . High resistance per millivolt and no appreciable error when used with thermocouples of different resistances and on connecting leads of considerable length . . . Sturdy construction, adapted to use under severe conditions without danger . . . So simple that instant readings may be made directly in either millivolts or temperatures by someone unfamiliar with the principles of pyrometry . . . On kilns or furnace installations, where "spot readings" are desirable—the Engelhard Rotary Switch permits separate readings from many points.

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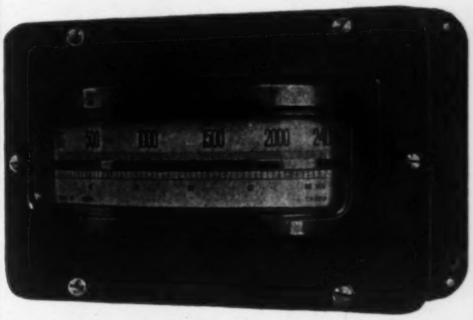

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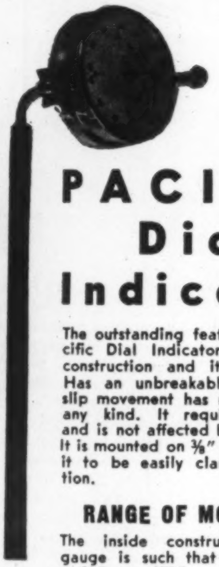

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The outstanding feature of the Pacific Dial Indicator is its sturdy construction and its 2-inch dial. Has an unbreakable crystal. The slip movement has no bearings of any kind. It requires no oiling and is not affected by dirt or dust. It is mounted on ⅜" rod permitting it to be easily clamped in position.

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The inside construction of the gauge is such that the hand has a ⅜" or .375" movement.

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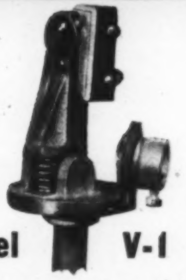

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Improved vertical switch designed for lower temperature range (0-300°F). Also available for —100° to 600° F. Adjustable range 50-150 degrees. Operating differential ½-3 degrees. Easy-to-set dial pointer inside case. Trouble-free snap action Micro-switch. 2¾" dia. x 4¼" high.

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AGASTAT
Unaffected by
variations in voltage
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...it's smaller!
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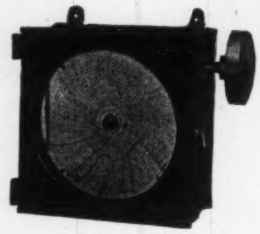

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8" Chart 12 or 24 hr.

Built for severe service. Users report 10, 12 or more years of trouble-free life. Powerful centrifugal speed-measuring element stays calibrated. Non-spill reservoir pen. Special chart paper. Rugged clock movement. Ideal for analysis of new War Effort jobs.

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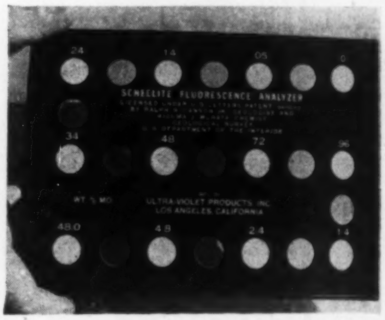
separate synchronous motor at pre-determined speeds. When the recorder is used in conjunction with Michigan Sine-Line checking equipment, synchronous device in checker is connected with the sine-bar table; recorder motor drives chart. Travel of chart is then such that 1" of chart movement represents 4° of rotation of the work-carrying spindle. When the independent synchronous motor drives the chart, speed of either ¼" or ½" per second is selected. Thus a continuous record can be made of continuous measurements along any surface which can be measured by the conventional ten-thousandths indicator. It is only necessary to replace the conventional indicator by one adapted to or designed for use with the electromechanical recorder. Magnification is ⅛"=0.0001" and chart permits dimensional variations up to 0.002" either side (plus or minus) of a central "0" line to be recorded. Operation: Three switches are mounted on control panel. The left switch selects the driving method (synchronous speed with checker, or constant speed by chart drive motor). At top right is lever for selecting chart speed. Center switch controls movement of pen. Right-hand switch controls direction of chart travel relative to that of part being checked. At top left is power supply switch. Recorder is designed for operation on standard 110-volt single-phase a.c. Accuracy is not affected by normal variations in line voltage. *—Michigan Tool Co., 7171 E. McNichols Rd., Detroit, Mich.*

Ore-grading Card for U-v. Fluorescence

New government-approved Scheelite Fluorescence Analyzer Card is designed for use in conjunction with ultra-violet mining lamps such as the "Mineralight" models (described in *Instruments*, Sept. 1942, page 383). Developed by R. S. Cannon Jr. and K. J. Murata of the Geological Survey, the card makes possible instant comparison of ore samples with standard type Scheelite examples to determine percentage of molybdenum content. Measuring 4" x 6", this card carries 12 fluorescent checking examples, each ½" in diameter, illustrating 12 molybdenum content graduations from 0% to 48%. Adjacent to each is a hole so that a test sample may be placed beside the example and examined under ultra-violet light to determine the value. In this manner, molybdenum content can be estimated easily and quickly within a negligible variation. Evaluations of new finds are greatly facilitated. Sorting and grading of ore in going operations can be handled with much more efficiency and speed.*—Ultra-Violet Products, Inc., 5205 Santa Monica Blvd., Los Angeles, Calif.*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Using a torque wrench (any standard make) as its measuring element the *STURTEVANT Spring Tester* will accurately measure the recoil pressure of a spring compressed to any predetermined length . . . tests compression springs up to 2½" OD and 7" length.

No Elaborate Setting Up—test platform adjusted for test length of spring by merely revolving on threaded vernier scale. Adjusted in a few seconds to within .003".

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INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place	Subject	Speaker
Atlanta	Georgia Society for Measurement & Control	D. D. Beach, P.O. Box 4569, Atlanta, Ga.				
Baltimore	Baltimore Industrial Instrumentation Society	Fred Pullen, Bethlehem Steel Co., Sparrows Point, Md.	May 21(D)	Maryland Academy of Sciences	Some Fundamentals of Instrumentation	M. F. Behar
Chicago	Chicago Society for Measurement & Control	Carl Hope, 2626 W. 31st Blvd., Chicago				
Hartford	Hartford Society for Measurement & Control	Stephen J. Zelle, Whitney Chain & Mfg. Co., Hartford, Conn.	May 18(D)	Hartford Electric Light Auditorium	Precision measurements with the use of optics	C. B. McCathron, Bausch & Lomb Optical Co.
Newark	New Jersey Society for Measurement & Control	R. F. Robey, 409 Orange Ave., Cranford, N. J.	June 1(C)	Public Service Terminal Restaurant	Comparison of control in boiler and process	J. B. MacMahon, Republic Flow Meters Co.
New York	New York Society for Measurement & Control	R. K. Farnham, 545 Fifth Ave., N. Y. C.	May 25(B)	Churchill's Terminal Restaurant	Special Instruments in the War	R. J. S. Pigott, Chief Engr. Gulf Research & Dev. Corp.
			June 29(B)	Churchill's Terminal Restaurant	Machines, Men and Meters	R. J. Kryter, Vice-pres. Esterline-Angus Co.
Philadelphia	Philadelphia Society for Instrumentation	George Hammer, Foxboro Co., 701 Otis Bldg., Phila., Pa.	June 16(B)	Engineer's Club	Rotameters and Their Secrets	Kermit Fischer, Pres., Fischer & Porter Co.
Pittsburgh	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh.				

(A)Meeting at 7:30, no dinner. (B)Dinner at 6:30, meeting at 8. (C)Dinner at 7, meeting at 8. (D)Meeting at 8, no dinner.

CHICAGO

J. F. Dillinger, Development Engineer, Western Electric Co., spoke on "Measurements of the Magnetic Properties of Metals" at the April 5 meeting. He first outlined development of the B-H and hysteresis loop curves, then explained how interpretation of these curves makes it possible to select metals for specific applications.

He described the various methods for measuring the magnetic properties of metals, the instruments and circuits used in each and the limitations of each.

Various commercial magnetic materials were covered, including those containing nickel and cobalt. The magnetic characteristics of each of the three metals in the so-called ferro-magnetic group of elements were pointed out, together with the special properties in which each excels.—R. L. WHAM

NEWARK (By telegram)

The regular monthly meeting of the Society for Measurement and Control New Jersey was held May fourth Public Service Terminal Restaurant Newark New Jersey 51 in attendance. The speaker, Mr. N. Schnoll, President Industrial Instruments Inc., Jersey City, New Jersey gave an interesting and instructive talk on electrolytic conductivity measurement in industry. Mr. Schnoll outlined the history, development, and manufacture of electrolytic conductivity apparatus and their application to industry. The meeting was followed by a lengthy discussion showing the keen interest developed in the subject. —N. E. CHANCEE

NEW YORK

Sixty-five members and guests attended the dinner which preceded the April 27 meeting which had an attendance of 85.

Mr. H. C. Roters, Director of Research, Fairchild Aviation Corp., gave us a highly informative talk on the design of electromagnets and their application to instruments and control devices.

He demonstrated the mathematical formulae on which the ideal designs of electromagnets are bared and the considerations to be kept in mind in design procedure so that the finished magnets will conform to these formulae. —BOB FARNHAM

PHILADELPHIA

Mr. J. C. Peters, Research Engineer of Leeds & Northrup Co., drew an attendance of 84 at the April 21st meeting. His subject was a most interesting one: "Automatic Control of Industrial Processes". He showed slides on air- and electric-operated types of Control. —GEORGE HAMMER

Manufacturers' New Literature

In this department we report ALL pieces of new literature pertaining to Instrumentation, received from the manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on this page.

K-142 **Cathode-Ray Oscilloscope.** The Dec. issue of *The Capacitor* covers practical oscilloscope design while the Jan.-Feb. issue is entitled "Seeing Patterns on the Screen." Cornell-Dubilier Electric Corp., Hamilton Blvd., S. Plainfield, N. J.

K-143 **Aerovox Research Worker**—the Sept.-Oct. issue of this company organ has an article on "Design Data for M-Derived Type Filters." Aerovox Corp., New Bedford, Mass.

K-144 **Rheostats and Resistors.** Bulletin 550, 8½" × 11", 8 pages describes a new line of slide contact rheostats and fixed tubular resistors with adjustable band. The rheostats are single range type, protected or unprotected, and indicating four range types which are quite an innovation in the rheostat field. Besides panel mounting, rotary-drive rheostats can be furnished. Herman H. Sticht Co., Inc., 27 Park Pl., New York, N. Y.

K-145 **Signal Generator.** Bulletin 127, ½" × 11", 4 pages describes new additions to the R.C.P. line of electrical and electronic instruments. This bulletin describes the new model 703 Signal Generator, Model 419 Master Multitester in three models, models 416 and 418 Pocket Multitesters and the Model 446 A A.C.-D.C. Multitester. Radio City Products Co., Inc., 127 W. 26th St., New York, N. Y.

K-146 **X-Ray Quartz Analysis.** Bulletin 01, 8½" × 11", 4 pages covers a line of new fixtures and accessories. These accessories and fixtures will greatly extend the usefulness and versatility of the Philips X-Ray Quartz Analysis Apparatus. A few of the fixtures listed in this bulletin are Crystal Blank Holders, Rotating Wafer and Rotating Crystal Blank Holders, Edge Correction Holder, Angle Correction Holder and Bragg Angle Scale. Philips Metalix Corp., 419 Fourth Ave., New York, N. Y.

K-147 **Pneumatic Control.** Catalog N-00B, 8" × 11", 16 pages stresses the use of this equipment for regulation of pH, conductivity and other conditions, as well as temperature. This controller manipulates a diaphragm valve in order to maintain the regulation. The valve's opening is greater or smaller, depending on the pressure in its air chamber. In Micromax Control, this air chamber is connected to the control instrument by means of ordinary uncalibrated tubing or small piping. The controller is described as employing a system of electrical and mechanical balances which detects, while they are very small, any departures from the control point, and simultaneously changes the air pressure to correct them. The publication emphasizes the equipment's ability to re-set itself whenever necessary, so that all the forces which tend to upset the controlled condition can be neutralized—change in load, as well as in fuel or other controlled medium, radiation, weather, etc. The Micromax controller is described as completely factory-assembled, ready to be connected to valve, to thermocouple or other primary element, and to electric power. All control knobs, gauges, etc., are said to be at the instrument, for ready accessibility. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.

K-148 **Radio Tube Guide,** Form 1G, 8½" × 11", 72 pages is a new and completely revised edition of the RCA Guide for Transmitting Tubes, designed especially for radio engineers and technicians in the armed service and war industries. Written originally and carried through in the three earlier editions as a catalog for tube users, the present or fourth edition of the Guide transforms the booklet into an effective instrument of war. Demand for technical information on power tubes has increased in line with the tremendous increase in the demand for the power tubes themselves on the front line of battle. A supreme effort has been necessary to supply these tubes in the quantities required. Requirements of war production industries, broadcasting stations, police and defense users—necessarily taking second place—nevertheless must also be met to the best of the industry's ability. Commercial Engineering Section, RCA, Harrison, N. J.

K-149 **Deaeration of Boiler Feed and Process Water.** Bulletin 3005, 8½" × 11", 36 pages treats deaerators. Sections are devoted to: Flow diagrams including phoographs of installations described. Corrosion control. pH control. Metering deaerating equipment with V-notch recorder and electrical systems for recording flow at a distance, when the recorder is located on a centralized panel board. Cross section photographs and line diagrams in color clarify the operation of the Cochrane deaerators. Illustrations are shown of various designs that are constructed to meet space limitations and operating requirements. Cochrane Corp., 3120 N. 17 St., Philadelphia, Pa.

K-150 **How to Freeze Dimensions on Gages and Precision Parts.** News Bulletin, 8½" × 11", 2 pages covers current uses of sub-zero temperatures in the metal working industries. Deepfreeze Div., Motor Products Corp., 2313 Davis St., North Chicago, Ill.

K-151 **Air Express Wartime Wall Chart.** The Chart briefly details up-to-date information regarding the air and air-rail service that is constantly available to shippers throughout the country. As many of the readers of this publication under present war conditions will have need from time to time for super-speed transportation, this new chart will be of interest to them. Railway Express Agency, 230 Park Ave., New York, N. Y.

K-152 **Noise Primer.** The March issue of the General Radio Experimenter contains Part V—Practical Application of the Sound Level Meter. General Radio Co., 30 State St., Cambridge, Mass.

K-153 **Thread Roll Snap Gage.** Leaflet C-102, 8½" × 11" 1 page illustrates a gage which is claimed to be faster, longer wearing and no more expensive than ring gages. Vard, Inc., Pasadena, Calif.

K-154 **Photo-Electric Controls.** Specification Sheet 1, 8½" × 11", 2 pages illustrates the Series 70 controls for industrial processes. United Cinephone Corp., Torrington, Conn.

K-155 **Wheelco Comments.** The Feb.-Mar. issue of this publication has a very timely article entitled "Prolong Instrument Life." Wheelco Instruments Co., Harrison & Peoria Sts., Chicago, Ill.

K-156 **Split-Core Current Transformer.** Bulletin 842, 8½" × 11", 4 pages describes the split-core transformer for places where it is difficult or impractical to open a circuit for metering purposes. The advantages of the new transformer are given. Esterline-Angus Co., Inc., Indianapolis, Ind.

K-157 **Master Gages.** Folder, 8½" × 11", 4 pages illustrates a large number of views in the manufacture of gage blocks as carried out at the Savage Tool Co., Savage, Minn.

K-158 **Application of Current Transformer Calibration Factors to Watthour Meter Calibration.** The Duncan Register is published by the Duncan Electric Mfg. Co., Lafayette, Ind. No. 1 issue of 1943 contains the main article having the above title.

K-159 **Constant Voltage Transformers.** Handbook, 8½" × 11", 24 pages contains specifications of the Constant Voltage Transformers that are available as Standards. In addition to the Standard units, special transformers can readily be provided to meet almost any individual specification. Sola Electric Co., 2525 Clybourn Ave., Chicago, Ill.

K-160 **Thermoswitches.** Fenwal Facts, 8½" × 11", 8 pages deals with Selection and Application of Thermoswitches of particular interest to engineers; with Sensitivity, Differential, Lag and Overshoot, Heat Balance, Heat Gradients and Thermal Conductivity. Complete with charts and full explanatory copy, this issue was designed to show some of the principles of thermal control, particularly for those who are just entering the field. It also contains an explanation and picture of the new Test Stand. Fenwal Inc., 6 Main St., Ashland, Mass.

K-161 **Capacitors.** Catalog V-2, 8½" × 11", 4 pages lists specifications and characteristics of standardized oil-paper capacitors for government and industrial electronic applications. Solar Capacitor Sales Corp., Bayonne, N. J.

K-162 **Magnetic Reversing Switch.** Bulletin 4216, 8½" × 11", 4 pages, describes the new improved 5 H. P. magnetic reversing switch made as a single unit instead of being made up of two separate contactors. This design allows for reducing the switch to a compact size, eliminates internal wiring. It is especially suited for severe plugging service and other heavy duty. Large,

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Instruments, 1117 Wolfendale St., Pittsburgh, Pa. **(MAY 1943)**

Please have the following catalogs, etc., reviewed in this issue sent to me.

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I also desire further information concerning the following new products described in this month's "New Instruments" Department ....

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Company .... Position ....

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